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The Use of Geographic Information Systems To Facilitate Brownfield Redevelopment

by

Erik S. Balsley

Submitted to the Department of Urban Studies and Planning
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ABSTRACT

The redevelopment of old industrial properties that may be environmentally contaminated is one of the more difficult challenges a municipality can face. In many cities the regulatory framework designed to redevelop these "brownfield" sites has inadvertently hindered this process. New programs are now being developed that look beyond strict environmental criteria and utilize economic, social, and land use data to help guide the redevelopment process on most sites. As a result, more thorough data analysis of brownfields is now required in order to adequately utilize these new programs for site redevelopment.

At the same time brownfield programs are being redesigned, the use of geographic information system (GIS) technologies are becoming more institutionalized in the daily activities of municipalities and planning agencies. As brownfield redevelopment policy continues to evolve it can be shaped to take advantage of the capabilities of GIS, since complex accounting and analysis can help to improve and accelerate brownfield redevelopment.

A case study that pulls together existing maps and datasets isperformed using the City of Boston, as it is the municipality in the State of Massachusetts with the greatest number of contaminated properties. The study then focuses on the service area of Codman Square Neighborhood Development Corporation (CSNDC) to illustrate the steps required and the difficulties in developing a GIS for brownfield redevelopment. The CSNDC was chosen as it is typical of many redevelopment agencies faced with the difficulties of brownfields and because a good amount of state and city data were available to use in a GIS.

The case study shows how communities can utilize existing state and local data sources, rather than creating their own, to analyze brownfields using GIS. However, it is shown that improved data coordination, documentation, and support are the main steps that can be taken to use these data more effectively in tackling the problems of brownfield redevelopment

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I: INTRODUCTION

One of the most complicated issues a municipality can face is the redevelopment of its vacant lands, primarily those that have been previously developed for commercial and industrial use. These sites are often referred to as "brownfields" which are properties where reuse is complicated by actual or perceived environmental contamination.[1] In the past, the redevelopment of these sites has been complicated by environmental regulations that sought to return the levels of pollution on a site to "pristine" conditions where no contamination was present.

For most sites this remediation is extremely costly and all current and previous owners of a property have been at risk of being legally held responsible for these costs under these programs. As all sites have to be cleaned to the same standard regardless of their future use under these programs, the resulting remediation costs for industrial and commercial properties have been higher than they might be if certain uses could be accommodated without complete remediation. In addition the legal liability framework regarding who bears the cleanup costs on contaminated sites, has inadvertently created disincentives for developers to reuse these properties. As a result, site redevelopment has been hindered rather than facilitated by these programs. In an effort to facilitate site redevelopment, most of the recent revisions to brownfields legislation have begun to clear up uncertainties in the remediation process; make the clean up of properties voluntary; give the private sector more responsibility for remediation activities; provide economic incentives to redevelop certain types of sites; and create flexible clean up standards that are based on a site's end-use evaluation. These new programs make it critical to understand a site's social and political context, in addition to environmental concerns, when proposing redevelopment strategies for it.

Concurrent with these developments, the use of digital data in planning processes by states and communities continues to increase. As a result, the amounts of tabular and geographic data, which can be mapped through the use of a geographic information system (GIS), have increased as well. Increasingly specialized sets of data are being provided as the demand for data grows, to address

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[1] Connolly, Kathleen and Daddario, David. "How to Find the Green in Your City's Brownfields". *American City and County*. November 1995. Page 30

more complex and complicated questions. At the same time, GIS and information technologies are also becoming more established in the institutional framework of planning as their use continues to grow.

As the thinking about brownfield redevelopment has evolved at the same time the use of GIS is becoming more institutionalized, the two can be meaningfully brought together to improve the quality of brownfield site analysis. GIS can help gather together the various social, environmental, and economic data required of newer brownfield programs. By using GIS in these programs, the amount and quality of information pertaining to brownfields, and the spatial analysis of these sites, can be improved.

This thesis reviews the evolution of brownfields as a planning issue and examines how emerging GIS technologies can be utilized to aid and facilitate brownfield redevelopment. A case study of the land use surrounding brownfields in Boston, which is the community with the largest amount of sites in the state, will be performed. Rather than developing specialized data, existing data from various sources will be used in the GIS. The GIS will then focus on the service area of the Codman Square Neighborhood Development Corporation (CSNDC). The case study will illustrate how available information and an existing GIS structure can be accommodated to improve the understanding of brownfields. The thesis will conclude with conclusions and recommendations on how data can be improved and better coordinated to ease its inclusion in a GIS for brownfield redevelopment

Chapter 2 of the thesis will trace and analyze the evolution of brownfield policy while Chapter 3 will look at state and local data that can used in GIS for brownfield redevelopment and examine the tools available to analyze that data. Chapter 4 will look at the types of maps and data available from sources and outline a methodology on how to use. Chapters 5 and 6 present the Codman Square case study. Chapter 5 will outline what data was chosen and how the list of sites was mapped. Chapter 6 presents the results of data analysis using the GIS. Finally Chapter 7 will develop conclusions regarding the extent to which it is practical to assemble GIS datasets from different existing sources, for brownfield redevelopment.

CHAPTER II: THE BROWNFIELDS CHALLENGE

"Brownfield" redevelopment is one of the most discussed planning problems in America. As the economy has shifted away from heavy manufacturing and industrial, several cities have been faced with the challenge of finding new uses for these properties. Although no comprehensive inventory of such sites exists, limited data indicate that industrial uses generally occupied about ten percent of the land in older US cities.[2] As these sites often wind up vacant or under used, their loss can be said to have contributed to economic malaise in many communities. The very presence of abandoned properties can contribute to a community's sense of despair and drive property values down.[3] Many believe that to improve the economic health of the most economically distressed cities, these "brownfield" sites need to be returned to active productive use, either as centers for light industry or commerce.

Although many "brownfield" sites lie in close proximity to downtown areas, and are already tied into a municipality's infrastructure, they are often overlooked by developers. In addition to any site improvements that must be made developers are faced with the uncertainties of environmental liability and remediation costs on these properties. Further complicating site redevelopment in many urban centers, is that the risks from crime or poverty outweigh any known hazards created by old industrial pollution.[4] Many cities have also been completely built out and as a result inner city businesses often relocate to surrounding suburbs because land does not exist in the city to support their future expansion.[5]

When faced with the choice of developing a suburban "greenfield" site, or a brownfield with uncertain environmental liability and remediation costs, most developers have chosen to develop upon greenfield sites to minimize these uncertainties. While this minimizes the immediate costs of development, many are beginning to question whether greenfield development may prove more

[2] Urban Land. October 1994. Page 75.
[3] Connolly and Daddario. Page 30.
[4] Ibid.
[5] Iannone, Donald. T. "Redeveloping Urban Brownfields". *Land Mines*. November 1995. Volume 7. Number 6.

costly to society in the long run. It can be said that greenfield development contributes to problems such as air pollution, sprawl, and the plight of inner cities.

By moving employment centers farther from cities into undeveloped suburban areas, existing resources and infrastructure are not used effectively, while inefficient networks are expanded. As the job base shifts away from central cities into areas without mass transit systems, any resulting increase in automobile traffic can also contribute to air pollution. This type of suburban sprawl development hurts inner cities as older parcels are left vacant, and jobs shift to places inner city residents can not access unless they own an automobile.

Past Federal Strategies for Contaminated Sites

The first programs designed to deal with contaminated sites were primarily concerned with minimizing the immediate environmental risks to communities. These programs sought to clean up the sites and make those responsible for the contamination pay the remediation costs, when past and present property owners could be identified. However, this process increased the uncertainty of environmental liability and clean up costs to developers, making them hesitant to invest on a contaminated site without further assurances regarding these issues from the government. Also, by ignoring the other social and economic factors that play a role in site redevelopment, sites could not be cleaned up to different standards to reflect the ultimate use of the land. All properties had to be cleaned to a residential standard, although commercial and industrial uses could be cleaned to slightly lower standards without significant harm to the environment and surrounding residents. As a result, the regulatory system inadvertently created disincentives for redevelopment of these properties, stymieing market forces that might propel the reuse of older industrial sites, creating a time-consuming and cumbersome redevelopment process and promoting the perception of insurmountable institutional barriers to reuse.[6]

Most of the laws and regulations regarding contaminated properties are built upon the federal Comprehensive Environmental Response, Compensation, and Liability Act of 1980

[6] "GIS helps detail brownfields to spur revitalization". *American City and County*. December 1995

(CERCLA), which created the federal Superfund program to clean up hazardous waste sites. The act was amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, to deal with unresolved issues from the first enactment. Under this statutory framework, the EPA has the authority to determine which sites are contaminated by hazardous materials to such a degree that some sort of agency response is needed.[7]

Superfund was designed to deal with the nation's largest hazardous waste sites that posed immediate harm to the public. The most contaminated sites are placed on EPA's National Priority List (NPL), and are ranked on it by a formula that involves the proximity of the polluted area to residential areas, the nature of the chemicals involved, and whether or not drinking water had been contaminated.[8] Even if a property does not make its way on to the NPL, or was found to not warrant EPA action, information about the site is inventoried in EPA's Comprehensive Environmental Response Compensation and Liability Information System (CERCLIS). The program takes a worst first approach where the most highly ranked sites on the NPL are cleaned up before the others. If a property is placed on the NPL it has to wait for the EPA to directly control the site clean up.

In the past, less stringent environmental policies did not adequately regulate the disposal of many chemicals and their propagation into the environment. CERCLA set up clean up standards with low thresholds for many of these common chemicals, which applied to any site where there was a release or threat of release of hazardous material, with the result that everything from residential backyard spills of common automobile oil to large factories were lumped into the same designation.[9] In many cases sites were reported to EPA, and placed on CERCLIS, even if though the contamination present on them was minimal or non-existent.

Those involved with CERCLA have long complained that it was too big, cumbersome, and draconian in the measures it propagated.[10] In developing the program to address the nation's most

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[7] Slutzky, David and Jacobson, Lawrence. "EPA's Brownfield Initiatives". *Mortgage Banker.* July 1995.
[8] Harr, Jonathan. A Civil Action. Vintage Books. New York. 1995.
[9] Ibid. Page 14.
[10] Varady, Julia. *Contemporary Perspectives and Strategies for Transforming the Industrial Landscape.* Masters in City Planning Thesis. MIT. 1996. Page 13

serious hazardous waste sites, it strengthened and created strong and broad reaching powers to federal agencies to facilitate site cleanup. The legislation authorized the government to clean up these sites, and to pass the remediation costs on to all potentially responsible parties (PRP's) involved with the site. In some respects the measures were designed to correct past governmental missteps.

Under the Superfund legislation any past owner or user of a contaminated property was considered a PRP, regardless of whether or not they caused the contamination. Developers and lenders fear this designation as it means that are responsible for a site's clean up costs. As these cleanups are time consuming, they are also very costly. Sites that were identified by the EPA and placed on CERCLIS, but were not listed on the NPL, were stigmatized by the potential threat of these actions. Even if a property owner undertook a remediation activity on a minimally contaminated site that met state standards, those standards and clean up activity were not recognized by the federal government. If the EPA decided to later take action on these site, the developer could still be named a PRP.

Further hindering site redevelopment, was that a PRP could also be held legally responsible for any damage to others caused by the site or the release of hazardous material. Even if a site were investigated and later removed from CERCLIS, for not meeting Superfund's contamination thresholds, it still bared the stigma of being polluted. In many cases, misperceptions about the law meant many sites continued to be seen as contaminated and their property values fell, even though the EPA determined the site was not polluted. To avoid the potential costs of clean up and liability, developers often abandoned or did not maintain properties that were suspected or confirmed to be contaminated in efforts to thwart EPA action. Instead of facilitating the development and clean up of these sites, the CERCLA program helped to dissuade developers from approaching them.

The program was also criticized as being fraudulent, for stymieing normal market activity, and for hurting disadvantaged areas rather than protecting them.[11] These early laws required that all sites be returned to their original 'pristine' state where the chemicals were non-existent or at existed

[11] Ibid.

at minimal levels, which would be the safest for humans and allow for future residential development. This pristine standard did not take the future uses of a site into consideration. As most of the sites were within industrial and commercial zones, there was little likelihood for residential development in the first place.

Despite its flaws CERCLA was the first federal legislation that dealt specifically with hazardous waste cleanup. However it did manage to get sites cleaned up slowly and with high costs. Of the worst 1,300 sites, only about 200 have been eliminated since the program took effect.[12] This was because the regulatory framework CERCLA set up was too stringent and large and its funding too limited.

A History of State Programs for Contaminated Sites

Several states developed their own programs to deal with contaminated properties after CERCLA passed. These programs were created to address sites that were not contaminated enough to warrant Superfund actions. As these programs were modeled after Superfund, they approached sites in the same manner and faced similar complaints. Concerns about liability, cleanup costs, and cleanup standards helped contribute to the present day problems on these sites.

For brownfield sites in older inner city neighborhoods that lie in economically depressed areas, have higher crime rates, and are often abandoned, the fear of being held accountable for site cleanup and of liability, further hurt development of these sites. Even if incentives were offered to the private sector to ameliorate these other problems, developers and lenders would still be hesitant to redevelop them. The irrational approaches to urban land clean up and regulatory uncertainties have led to an unwillingness, on the part of owners and their investors, to expand or locate their businesses on brownfield sites.[13] In addition communities felt removed from the process, making them feel unable to help propose reuse programs with their concerns in mind.

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[12] Wright, Andrew G. and Roe, Andrew. "Brownfield Cleanups Debug Development". *ENR.* April 28, 1997. Page 32.

[13] Goldsmith, Stephen and Taylor-Woodward, Pat. "Brownfield Site Development - A Great Hope for American Cities". *Public Works.* February 1996.

As many state waste site programs have entered their second decade, their problems have become apparent. As a result, reforms to most state programs dealing with contaminated properties, attempt to address both the underlying economic concerns and the core environmental problems of brownfields which are contaminated commercial and industrial properties.

Most of these more recent and current brownfield strategies have developed what can be considered a toolbox of programs to facilitate site redevelopment. The programs either give developers economic bonuses such as tax breaks, tax credits, or access to special state funds; reduce uncertainties in the cleanup process by creating generic cleanup standards; gear cleanup standards to the future uses of sites; clarify criteria for reviews, and set performance standards for many developments; reduce liability through the use of "covenants not to sue"; or provide liability relief for site cleanup actions initiated by a developer. These programs can then be combined to meet the needs of a specific site while keeping site redevelopment in the context of a larger strategy.

Many state programs have also taken steps to privatize many aspects of their waste site clean up efforts to speed up and provide flexibility to the process. These programs are also clarifying standards to reduce the uncertainties associated with site clean up, to facilitate remediation activities by private developers and investors. Sites are also being nudged back into active use by the clarification and reduction of environmental liability. This reduces the perception of the risk associated with these properties to developers.

These programs try to correct the market conditions which hinder site redevelopment. Their components are designed to provide the appropriate amount of liability relief and financial assistance to facilitate site reuse. In general, privately owned sites with strong reuse potential where property values exceed cleanup costs are least likely to require additional financing assistance.[14] However, the state may still need to provide increased liability relief on these properties in order to induce private remediation and development actions. The most troubled sites, those with large amounts of contamination and which face adverse economic conditions, are those that definitely need a combination of both liability relief and financing assistance to foster their redevelopment.

[14] Metropolitan Area Planning Council. *Metro Boston Brownfields Status Report.* June 1995.

As brownfield redevelopment is beginning to be viewed as an environmental and economic problem, in many states the agencies for these issues have begun to develop joint brownfield redevelopment programs. This interdisciplinary approach requires the coordination and cooperation of these agencies, in their efforts to clarify and coordinate the roles of federal, state, and local government in cleanup and economic development efforts, provide support for job training and development activities related to brownfields reuse, standardize remedies for various types of contamination, and continue cooperation with industry and professional and civic organizations to investigate and develop better approaches and techniques to address the cleanup and reuse of brownfields.[15]

As the demand for brownfields is influenced by the development patterns in surrounding areas and by the type and quality of development proposed for them, more comprehensive approaches to site development are being taken.[16] To most effectively redevelop these sites, one needs to take their larger economic, social, and political surroundings into consideration when formulating a redevelopment policy. Environmental concerns are just one part of the problem, and can not be the sole focus in brownfields programs. Solutions need to be sought in order to spark urban revitalization on a larger scale.[17]

The Evolution of the Massachusetts Strategy

Like most other states, Massachusetts began its statewide hazardous waste site clean up program after Superfund was passed. Not only did the two programs use similar language they also addressed the problems posed by contaminated sites in the same manner. Massachusetts' early efforts at waste site cleanup were primarily concerned with eliminating environmental risk, while the social and political aspects of site redevelopment were overlooked.

Massachusetts enacted its Superfund law in 1983 when the state legislature passed Chapter 21E of the Massachusetts General Law. This document sets out the definitions and basic strategies

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[15] Black, Thomas J. "Brownfields Cleanup". *Urban Land.* June 1995.

[16] Iannone, Donald T. "Sparking Investment in Brownfield Sites". *Urban Land.* June 1996. Page 43

[17] Ibid. Page 64.

to be used by the state in dealing with contaminated sites. Chapter 21E also requires the state monitor and inventory all confirmed and suspected hazardous waste sites. It also established strict joint and several liability, meaning that everyone - municipalities, innocent owners, lenders, and others - can be held fully liable for all the contamination on a site.[18] The specific regulations proposed by Chapter 21E are fully described in Massachusetts Contingency Plan (MCP), which was last amended in 1992. The MCP is a thick document that sets out the specifics of the 21E programs and the environmental standards to be used in these programs. Together the two documents determine contaminated site cleanup policy in Massachusetts.

By 1992 it had become obvious that the older focus on environmental concerns in site cleanup in isolation from the related site economic factors was not working. As every site action had to be performed and monitored by the state Department of Environmental Protection, site cleanups were tremendously slow and costly. The Department was also suffering from a backlog of sites. Less than 25 percent of the confirmed and suspected abandoned or "orphan" sites were being assessed or remediated, and the backlog of sites was growing rapidly.[19]

In addition many spills were not reported to the state by landowners who feared the high costs and liability associated with cleanup. Even if the levels of contamination were very low, a developer would have to wait for the state to clean up the site and pay for that action. They could not undertake clean up actions on their own initiative. Lenders also avoided providing funds to landowners of contaminated land for fear of these costs and liability. Because of these problems, a property on which a spill was reported was stigmatized as unclean. Landowners often chose to not report parcels on which a spill occurred, or where contamination was minimal, to avoid the liability and costs of state action on the site.

As the deficiencies to this approach became apparent, methods that addressed economic and environmental concerns in brownfield redevelopment were proposed. In 1992, Chapter 21E was amended and on October 1, 1993 substantial changes to the MCP took effect which redesigned the

[18] MAPC. Page 2.
[19] Ibid.

state's clean up program. The main changes introduced more flexibility into the program and provided the private sector with more responsibility and flexibility for site clean ups. Standards for reporting, assessing, and cleaning up releases were also clarified. A landowner may now voluntarily undertake a response action by hiring a Licensed Site Professional (LSP) to clean up smaller spills of more common chemicals. These environmental professionals are licensed by an independent state board to undertake these types of actions. In order to make sure that these actions meet state clean up standards, DEP audits a certain amount of clean up actions taken by LSP's each year. This leaves the state to handle only the most serious contaminated sites where state oversight is most needed, the Tier 1A sites in the state's classification scheme.

The new regulations have also changed other aspects of Massachusetts' waste site cleanup program to spur brownfield redevelopment. They outline procedures to clean up small problems quickly, clarify release notification thresholds that screen out problems not likely to pose significant risks to the public or the environment, establish performance standards to set the level of investigation by the nature of the contamination, generic standards for common contaminants, consideration of the future uses on a site to determine cleanup standards (commercial developments need no longer clean up to residential standards), and the establishment of Response Action Outcomes (RAO's) which create clear endpoints to the process. All of these steps reduce landowner uncertainty and help spur on private remediation activities. In addition the amendments clarify the liability of secured lenders as long as certain conditions are met, to reduce these parties' uncertainties. Municipalities have also been granted exemptions from liability when then obtain contaminated sites on liens or non payment of taxes.

The state has also developed the Clean Sites Initiative to further aid the state's brownfield strategy. It is a joint program of the Executive Office of Environmental Affairs, the Department of Economic development, DEP, and the Attorney General, which offers liability relief to people who clean up and develop sites with one of the state's Economic Target Areas, the state's most economically distressed areas. This liability relief is in the form of Covenants Not to Sue, which relieve a landowner from future liability for damage to natural resources on and around a site once cleanup is finished. However, these arrangements do not cover liability from new releases or other third party lawsuits. These convenants can be transferred to future landowners in the event the land is sold. Other economic incentives in the revised program include a 5% state investment tax credit, a 10% abandoned building tax deduction, priority for state capital funding, and special municipal tax benefits.[20]

Massachusetts is also proposing more changes to the brownfield program in the proposed legislation, "An Act Ensuring Environmental Cleanup and Promoting the Redevelopment of Contaminated Property". Amendments to Chapter 21E will provide more liability relief for new owners who clean up their sites to DEP standards. It also extends liability relief to other parties. It will also set up three new financial assistance programs for brownfields. It will set up $15 million in loan guarantees from the Redevelopment Access to Capital Program to encourage loans from the private sector, $15 million from the Industrial Sites recycling Fund in low-interest loans and grants for site assessments and cleanup for projects in economically distressed areas, and a 25 percent tax credit to reward "innocent" developers and businesses who clean up contaminated sites in Economic Target Areas.[21] Future envisioned changes to the MCP look to further speed up site clean up and clarify more standards.

The EPA Brownfields Action Agenda

While states and municipalities restructure their brownfield policies, the Environmental Protection Agency issued its Brownfield Action Agenda in January 1995. The several programs setup by the agenda take the approach that environmental cleanup is a "building block to economic development, not a stumbling block." The four parts of the program are Brownfield Pilot projects, the clarification of liability and cleanup issues, partnerships and outreach, and job development training.

[20] Varady. Page 17.
[21] Massachusetts Office of Environmental Affairs. "Massachusetts Brownfield Strategy". March 13, 1997.

The Brownfield Pilot projects are the most visible component of the EPA's program. They are intended to "provide the EPA, States and localities with information and new strategies for promoting a unified approach to environmental assessment, cleanup and redevelopment." 50 National Brownfield Pilot projects have been supported during 1995 and 1996. A Pilot project receives $200,000 from the EPA, to "support creative two-year demonstrations of assessment activities leading to cleanup and redevelopment decisions." Each of the 10 regional EPA offices have also set aside funds for smaller Regional Brownfield Pilot Projects as well. Those municipalities that receive funds can use them to survey and assess their brownfields, but can not use the funds for clean up activities because of federal restrictions on them. GIS applications are often developed with some of these funds to help compile the survey and assessment information together. This not only coordinates data, but allows its true geographic scale to be observed.

Municipalities that receive Pilot funds can use them as a device to leverage other private and public funds to create and support a more comprehensive brownfield redevelopment program. In this manner, most pilots have brought together community groups, investors, lenders, developers, and other parties together in the municipalities to develop unique approaches to their brownfield dilemmas. As these approaches are developed, the EPA offices follow them closely and obtain information about them. Other communities can go to EPA and use these projects as models as they develop their own local brownfield strategies. In this way the EPA acts as an information clearinghouse for brownfields data.

The EPA has also clarified liability and cleanup issues, through the Action Agenda. These steps are attempting to remove the apprehension and misunderstanding about liability for contamination which developers did not create. These measures are also working to reduce the exaggerated risk associated with these sites to foster their reuse. Already tackled are purchaser liability, the liability of owners of property containing contaminated aquifers, municipal acquisition liability, and lender liability at underground storage sites. In addition 24,000 sites have been removed from CERCLIS where the government planned no further actions. The EPA is also trying to reach agreements with many states to give cleanup actions completed under voluntary state programs the same authority as federal approvals. This reduces the uncertainty associated with cleaning a site to state standards, by not requiring federal government to approve individual clean up actions on these sites.

The EPA's Regional Brownfields Coordinators play a key role in providing brownfields information to improve the understanding of brownfields through outreach and partnership programs. They help to improve communications between the regional EPA offices and headquarters, check up on and obtain information about pilot projects, and help communities to propose regional pilot projects. EPA is also working more closely with other Federal agencies to improve government's overall response to these sites as well. In addition all projects are trying to increase the workforce in a community through education opportunities associated with the sites.

EPA's approach allows states to develop models of action suited to their own needs. By requiring documentation on the Pilots as a condition for their approval, the EPA is acting as a clearinghouse for data on brownfield redevelopment programs. Liability concerns are also being reduced for those who were not directly responsible for site contamination. These steps are helping to attract development to these sites, and allow other municipalities to learn from the approaches others have taken to brownfields.

Brownfield Pilot Project: Bridgeport, Connecticut

The Bridgeport Pilot Project was one of the first three Brownfield Pilots to be awarded and has been one of the most closely watched as well. Bridgeport is one of the oldest industrial centers in the state of Connecticut. As its industries have either shut down or moved away from the city, many of these industrial properties have been left idle or vacant. These sites are also surround by and face such inner city problems as crime, poverty, and general economic malaise. There are over 400 such documented sites in the city.

One of the primary reasons the City applied for a Pilot was to help it identify the extent of its brownfields problem. It was also part of the City's larger vision to encourage economic development and long term growth and prosperity for its residents by returning contaminated properties to productive use.[22] As part of this larger picture, the City created the Community Linkage for Environmental Action Now (CLEAN) Task force which was representative of all involved public and private interests. Although initially geared as a sounding board for the project, it was also designed to reach out into the larger Bridgeport community. The first step the City took towards reaching its broader goal was a field study to identify the vacant, underutilized, or abandoned properties. Sites already being remediated or targeted for redevelopment were excluded.[23] 205 properties were identified , which were then geographically grouped together to form 23 potential redevelopment sites.

Information for each site, was then entered into a GIS and database application. The information was broken down into several criteria based on environmental inventory data, physical characteristics, and marketing indices.[24] In addition to environmental data, site size, ownership, zoning, access, the presence of buildings, tax liabilities, and market demand were among the criteria determining a site's redevelopment potential. On each site, a numerical value between one and five was assigned to each characteristic, with five being the most desirable. Each criertion was also given a weight value between one and five, to represent its importance to site redevelopment. The weight and characteristic score for each criterion were then multiplied together on each site and totaled to obtain an overall site score. The strongest candidates for site redevelopment were those with the highest overall scores.

In the end six sites were selected for further study as areas in which to focus redevelopment efforts. Although the Pilot has ended, Bridgeport is continuing with its broader Brownfield Initiative. The City's EPA grant leveraged over another $2 million in federal and State resources to aid its efforts. The project not only shows how the Pilot program can help a city inventory and prioritize its brownfield sites for redevelopment and can use the grant to leverage additional funds, but how GIS can be used to effectively compile diverse spatial information to better inform and shape brownfield redevelopment.

[22] Executive Summary: The Bridgeport Brownfield Pilot Project. December 1996.
[23] Ibid. Page ES-2
[24] Ibid.

The Bridgeport Pilot Project built many of the data sets it used from scratch, by entering the data from the site surveys. However, most communities do not have the funds available to undertake such a process. By incorporating existing state and local data into a GIS brownfields analysis can be performed within a typical existing city GIS so data and a system do not have to be built from scratch. This process would avoid the costs of developing data, and may allow brownfields data to be more easily linked to other information. To illustrate these advantages we will develop a GIS that uses existing data for the Codman Square area in Boston. Before the Codman Square GIS is presented, we will discuss the context and issues with using GIS in general. We will then describe what data are available for a brownfields analysis and how it can be used in a GIS.

Chapter III: Exploring the Context of GIS

Data in a Statewide GIS Framework

As the approach towards contaminated sites has evolved from a purely environmental into a social, political, and environmental framework it has become more important for communities to be better able to understand all these factors relating to contaminated sites. With an increased understanding of the underlying context of contaminated properties, cities and states can develop appropriate local and regional strategies to facilitate and target their redevelopment. To the extent that GIS can be used as a tool to track and better understand the spatial scope of brownfields it can improve the level of knowledge about the sites.

Many states, including Massachusetts, have state programs in place to develop a statewide GIS program. While working towards developing a library of statewide digital data, the programs have also been working to improve the general quality of digital data provided. The Executive Office of Environmental Affairs' Massachusetts Geographic Information System (MassGIS), is one state program of this type. Like many of its sister programs, MassGIS was originally set up to develop a statewide set of digital environmental data, as indicated by its location within the environmental branch of state government.

One of the main reasons states began to develop statewide GIS programs with an environmental focus was the multi-juridistictional nature of these problems. Unlike many political problems, environmental issues tend to not follow man-made, artificial boundaries. These situations such as the protection of aquifers, wildlife, and flora tend to cross local, county, and state lines due to their very size. This makes it very difficult for one community or county to acquire the resources necessary to develop these data.

These state programs were designed to fill the shortfall, and provide the resources, to support and develop data for a GIS. The first state coverages to be developed tended to be of United States Geologic Survey soil, topographic, and hydrological maps. As these agencies became established, and states faced increased pressures to provide data, many of these programs were called upon to expand their scope to include non-environmental data. These agencies and their resources were already in place, so most states saw no reason to duplicate efforts by creating GIS programs in other state departments. The coverages of such non-environmental things include land use, transportation networks, and digital orthophotos and can be used for non-environmental analysis, or be combined with other state data to perform more complex environmental analyses.

In this framework, the question shifts to what data can be used for brownfield redevelopment efforts. Environmental data can be used to identify environmental resources affected by contamination, while non-environmental data can be used to better understand the context of these sites, so reuse strategies can be better designed to complement their existing context. We will now look at how typical state provided coverages can be used to perform these analyses, by looking at how MassGIS data layers can be used to better document the spatial distribution of brownfield sites.

Among the environmental data provided by MassGIS is a layer of aquifers in the state. This coverage can be used to determine whether or a spill may affect a groundwater or drinking water supply. This analysis can be useful in identifying the possible extent of site contamination and related liability. In addition, Masschusetts' brownfield program, like many other state programs, requires that contaminated properties located on top of a identified future drinking water source be cleaned to the highest standards. For a fee, MassGIS can map out a site and its proximity to such sources for developers. Layers identifying areas of environmental concern and wildlife habitats can be used to help determine the natural resources affected by contamination. This can help reduce the uncertainty associated with these sites.

Non-environmental data layers from MassGIS can also aid in documenting brownfield sites. Among these coverages are the 1995 TIGER files produced by the U.S. Census Bureau, land use maps from 1985 and in some cities 1990, and maps of major roads and other transportation networks. Land use data is useful as it can help a community help determine the best future development for a site in keeping with its surrounding uses. Economic data in the census can help a community look at a site's economic potential and help the municipality to develop measures to make less attractive sites amenable to development. Social data contained in the census can also help a community better understand the social environment around sites so redevelopment strategies can better meet the needs of surrounding residents. The roads and transportation network layers provided by MassGIS can help to identify accessible sites to which redevelopment efforts can be focused.

There is a great deal of data that is provided by the state that may be of interest to municipalities and communities analyzing their brownfields. The exact data to be used in any analysis will depend on which aspect of the brownfields dilemma is being studied. However, state data may not be suited to in depth analysis as it often lacks the precision and depth of locally provided information, such as assessor's data or land use surveys. We will now describe typical local data sources and how they can be used to refine analyses that use state data. We will also discuss some of the difficulties in combining data from different sources.

Discussion of Local Data Sources

One of the main benefits to using local data in a GIS is its local scale. Most local coverages group data at a parcel level and cover smaller geographic areas. As a result the data is often much more detailed and can highlight trends in the data that can be overlooked in state coverages that aggregate data at a larger level. The most comprehensive source of local data is often assessor's data, which contains detailed ownership, land use, and land value information for each parcel in a city. Many cities also maintain coverages of their public facilities, such as police stations, polling places, schools, medical facilities and fire stations. Data may also be available from local fire, police, and the building inspection departments. These data sources can provide a very detailed view of a neighborhood that can not be accomplished using state data alone.

These sources can be used in a brownfield redevelopment GIS in many types of analyses. The assessor's data can be used to obtain the average land value, building value, and lot size of brownfield sites. Combining these analyses with an analysis of the land use information in the assessor's data can add depth to the analyses. A community can use the results to search through the assessor's data to find sites with similar characteristics, that may be contaminated. The land use data can also be used alone to determine the land use context of many brownfield properties. Building inspector's data can be used to determine the quality and value of buildings on brownfield parcels, which may affect the choice of redevelopment strategies. Finally fire and police data can determine whether a contaminated property faces higher fire and crime risks which can reduce the marketability of the site. If these risks are identified, a reuse strategy can provide ways to minimize them.

While local data can be included in a GIS to perform many important analyses, some communities can build their own databases of brownfields information, such as some of the communities that have received EPA Brownfield Pilot Project funds have done. Although these funds are not specifically earmarked towards the development of GIS applications, several communities have used them to incorporate the data from assessment and inventory actions into a GIS. However, this approach is costly as it requires surveys to be performed and data to be prepared for its use in a GIS. Even though such efforts produce very detailed data sets they can be removed from other state and local GIS efforts, making it more difficult to relate them to other state and local information.

Combining Data from Different Sources

Given the amounts of available state and local data, they can be brought together to ensure a more complete analysis of brownfield sites. The state data can be used to observe larger trends relating to brownfields sites. Local data can then be introduced to refine the results of these analyses and give them added depth. However, there are a few issues that can complicate how effectively data sets from these different sources can be brought together to facilitate spatial analysis.

Geo-referencing data

In many cases data may only exist in a tabular format and not be associated with geographic map features, which would prevent it from being mapped. A process called geo-referencing can associate geographic locations or features to each record in the data. Once data is associated with geographic features and coordinates, it can be mapped, overlaid, and cross referenced with other geographic information to perform spatial analyses. Geo-referencing can be done with the built-in facilities of most GIS packages. To illustrate how it is done we will go through it using a list in tabular format provided by the Massachusetts DEP of properties where a spill of hazardous material was reported to have occurred prior to October 1, 1993. A brownfield is a site that is, or is thought to be, contaminated so this list can serve as a list of brownfield sites. This will highlight the nature of complexities in geo-referencing with respect to coordinate system, precision, the location of actual parcels, street spellings, and some of the reasons for map inconsistencies when maps are brought together.

In the first step of geo-referencing, the computer will automatically match records to geographic features. The computer searches through an indicated field in the table that contains location information, and will find the corresponding map location. This information can be listed as a street address, latitude and longitude, geographic place name, or as map coordinates. Latitude and longitude can be determined for a location from the field using a global positioning system (GPS). As location information can be stored in many ways, there are many maps that can be used in the geo-referencing process.

Data can be mapped to street addresses in the U.S. Census Bureau's TIGER line files, to a map that uses latitude and longitude for measurements, or to a map that stores the geographic place names of its features. As it would be difficult to map each and every street address to a precise latitude and longitude, the map used in geo-referencing will depend on how location information is stored. Once a record has been matched it is represented as a point, line, or polygon in a new map and the geographic coordinates of the feature recorded. The map that is created can then be used by itself or with other coverages for spatial analysis. As the location of contaminated properties is stored as street addresses, they can be mapped to TIGER files and each report indicated by a point on a map.

TIGER is a coverage of street centerlines, whereas the parcel data represents streets as voids between parcels. In addition, the TIGER files were derived from 1:100,000 scale maps, which is smaller than the 1:2,000 scale maps typically used to survey and map the parcel coverages, and can be off by a block or more in urban areas. In addition when addresses are matched to TIGER files they are mapped to an interpolated address. TIGER represents each street as a series of points and straight line segments . However, TIGER stores address ranges as a set of numbers between intersections. When an address is matched using TIGER, the computer looks through the ranges for each street and interpolates where along each segment a point lies. It is not an exact match.

The geo-referencing process generally involves two steps. In the first, the machine automatically matches the location information data to features on a map. However, in some cases information will not match exactly as data in one of the tables can be missing or misspelled, or two possible locations can be found on the map for a location. This results in a record not being mapped. An example of the former case would be the site listed at 240 East Berkley St. As a result of a missing e, it would not be mapped to 240 East Berkeley St. Sometimes when addresses are reported by common name, similar problems occur as with the release reported to have occurred at 1154 Morrissey Boulevard. It would not be mapped to 1154 William T. Morrisey Boulevard on the TIGER files, because the common name for the street was used. An example of the latter case would be the release reported at 15 Washington Street. It would not be automatically matched to the TIGER files either because there are several Washington Streets in Boston. It can only be mapped if other site information can be found for it.

As a result, the geo-referencing facilities of many GIS packages, also provide an interactive geo-referencing function to match these records. If a site could be mapped to several addresses, these processes would allow a user to look at more information from the report information to help determine which would be the appropriate address. In the case of the site at 15 Washington Street, we notice that it is located in the BRI district, indicating it is located at the Washington Street in Brighton. If a site had a misspelled street address, as in our earlier examples, a user could look through the TIGER file street names to find and match the record to the appropriate street. These processes can also allow records which can not be geo-referenced by location information, either automatically or interactively, to be drawn or placed on a map by hand. A site listed at North Station would not be able to be matched to TIGER files which do not record the name of institutional uses. By looking up the address of North Station in the phone book we find it is located on Causeway St. and we place a point on the map of sites at that location.

Geo-referencing allows a data set to be represented as features on a map, in our case as a map of points that represent an individual contaminated property. Each record is associated with its appropriate map feature and its coordinates, which are recorded in the projection system of the geo-referenced map. The map can then be used with others in spatial analysis. However, differences in projection system, which is often encountered, can be another difficulty encountered when maps from different sources are combined.

Resolving Differences in Map Projection

A projection system can be thought of as a grid on which a map of a portion of the earth's surface is drawn on a two-dimensional piece of paper. When data are geo-referenced to a map, the location information that is associated with the data are its coordinates in this map system. Some of the most common projection unit types are latitude and longitude and State Plane feet. By using a projection system to record location information, data can be more easily cross-referenced and used together. The data will all be associated with a standardized system that is common to other maps.

Any of the projection systems can be used to associate data with geographic features, the choice of one will depend on the projection of other maps that will be used and the size of the geographic area. However, if two maps are in different projection systems there can be some difficulties. We will demonstrate the difficulties by using a hypothetical example of a street map in a latitude and longitude projection and a parcel map in a state plane system, which cover the same geographic area. Since projection systems are basically a set of numbers indicating location, both maps will be drawn using one of the systems. If the first map drawn was our street map and we tried to draw the parcel map both would use latitude and longitude, even though the parcel map is in state plane. The coordinates of the parcels, although they represent points in another projection system, would be mapped as if they were latitude and longitude coordinates. Although both maps are of the same area, they will not match up when drawn together.

Since projections involve non-linear transformations, two maps using different projection systems can not be easily overlaid simply by shifting and scaling one of them. U.S. maps with curved and straight northern borders result from different classes of map projection. However most GIS packages provide tools that can convert a map in one projection system to another. As projection systems are numerical, mathematical formulas can interpret coordinates in one system to another. In order for maps to be converted it is necessary that the projection of each be known so the appropriate set of calculations is used to convert one map into the projection system of the other. In our example the parcel map would be converted into a latitude and longitude system. The two maps can then be drawn on top of each other to facilitate spatial analysis.

However, even after projection differences are taken into account maps may not line up correctly. As maps can come from different sources, they may represent the same data differently. For instance TIGER street files do not always line up with roads represented on a parcel map in Boston, as mentioned earlier. If the analysis of data does not require coverages to line up exactly, things can proceed as usual. However, if an analysis does require an exact match one of the coverages must be edited to more closely align with the other data. Several GIS packages have features that allow maps to be edited. If a brownfield site, that was matched to a location using the TIGER files, does not fall on top of the parcel with the same address, it can be moved to the appropriate location. Similarly lines can be added or removed from a coverage to more accurately relate to other data. In some cases maps can go through a rectification or other process or other "rubber sheet" adjustments, so they can better match spatial features in other maps.

In addition different GIS programs store maps in different formats. If a map is an ArcInfo coverage it can not be directly used in MapInfo. As a result, there are some programs that will allow coverages to be converted from one format to another so they can be used in multiple programs.

The choice of format depends on the format of other maps, and what GIS program will be used for later stages of the analysis.

Once these problems, if they exist, are fixed data can be analyzed spatially. Geo-referencing, projection system corrections, map editing, and coverage format conversions can allow data to be more easily used for spatial analysis. There are many types of spatial analysis and programs which can perform them. The next section of this chapter describes the basic characteristics of most spatial analyses that can be performed using GIS.

Spatial Analysis Using GIS

GIS can be used to perform many types of spatial analysis. The most common are buffer, cluster, and intersection analysis, and each is performed differently. Some of the analyses require very specialized tools that are available in the more expensive GIS packages. Generally most GIS packages allow for some basic editing and analysis, but more sophisticated tools are needed for more complicated buffer and intersection analyses. Each type of analysis will be described briefly below.

A cluster analysis is one of the more simple types of spatial analysis. It is most useful to determine the spatial aspects of a data set. If we wanted to find areas with a large concentration of brownfield sites a cluster analysis would be useful. The map would be drawn and areas with high concentrations of points identified. This can be done either by the GIS and its facilities, or by eye, as the mapped data can be surveyed to find areas with higher concentrations of reports. Most GIS packages have limited tools for formal analysis of clustering using spatial statistics and narrow clustering algorithms. If more than a basic analysis is desired, the data may have to be moved to a statistics package.

A buffer analysis is slightly more complicated. A buffer is drawn around records in a data set and data within and outside it are analyzed. It is an inside versus outside type of analysis which is useful in determining the characteristics around certain areas or whether certain areas are different from the rest of the data set. We can again demonstrate such an analysis using our brownfield map. If we wanted to find out the land use characteristics around the sites for instance, we can buffer the sites by an appropriate distance. We can then use the buffer to clip out the land uses on the map that lie within the buffer of each site. We can compare the land uses each around the sites to those in the city to see if the brownfields lie in a different land use context.

One of the more complicated analysis to perform is an intersection of two coverages. In this type of analysis certain areas from one map are combined with those from another. These analyses are performed when one wants to find areas that have characteristics from both coverages. If we wanted to determine which parcels were within a certain zip code in Boston we would perform this type of analysis. We would intersect a map of zip codes with a parcel map. We would then look at the new intersected coverage and find parcels that have been assigned the appropriate zip code.

In general more common and less expensive GIS packages such as MapInfo and ArcView can perform some form of basic buffer and cluster analyses. However, these packages do not allow coverages to be adjusted and intersected, in ways the may be needed to cross-reference data from different sources or to perform more complicated analyses. Efficient tools for adjusting zip code boundaries or aquifers to match parcel boundary details and avoid "slices" which occurs when coverages do not line up exactly, due to digitizing errors can require the use of more sophisticated GIS packages. More expensive programs such as ArcInfo must be used to do this. In addition some data may be better interpreted using database programs such as Oracle or Microsoft Access. These programs can perform more difficult analyses of tabular data associated with a map, such as averages and medians, a lot faster than many GIS programs, if they have such features. However, several GIS packages now can provide direct links to these programs to take advantage of these functions.

With an understanding of GIS and data in a state and local framework, the question of how these technologies and data framework can be accommodated in brownfield redevelopment programs can be addressed. We will develop a methodology that utilizes the technologies and existing data to address issues pertaining to brownfield redevelopment in the next chapter. This methodology will then be applied in developing such a GIS system for the Codman Square Neighborhood Development Corporation in the subsequent two chapters. In doing this we can address whether or not GIS and existing data, in general, can be brought together to facilitate meaningful spatial analysis for brownfield redevelopment.

CHAPTER IV: USING GIS TO TACKLE THE BROWNFIELDS CHALLENGE

Using GIS in the Context of Brownfields Policy

Given that most recent proposed legislation is looking beyond narrow environmental guidelines and standards to facilitate site development the analysis of brownfield sites has increased in complexity. The biggest stumbling block to understanding these sites still remains determining their past and present ownership. However, given the broadening of the frame from which brownfields are approached the question becomes one of how existing environmental data can be combined with social and economic information to ensure a more comprehensive analysis of brownfield properties.

Many communities and agencies dealing with brownfields may not even have any idea of the extent of what they are facing. Even if a list of sites exists, it is difficult to visualize their extent until they can be placed on a map. Though much has been written about the characteristics of brownfield sites, there are few cases where these statements have been made with any certainty. By using existing state and local data in a GIS, communities and local agencies can perform simple analyses to eliminate many of the uncertainties about their brownfields and develop a more complete understanding of them. This knowledge can help a community take advantage of the opportunities available in brownfield redevelopment programs.

The "traditional" environmental focus in past programs dealing with contaminated property, resulted in very focused examinations of these sites. Contaminated properties would be identified and strong efforts undertaken to identify any property owner or user who was a potentially responsible person. These parties, when found, would then be responsible for the costs of remediating the site. GIS and other information technologies were limited in their application in this approach. They could be used in this process to identify past and present users of a property, if such data were available, or to document what types of contamination were on each site. There was no need to use GIS to explore other aspects of contaminated properties.

However, the most recent and proposed state brownfield programs have become more comprehensive in their scope. They have developed new criteria and guidelines to facilitate site redevelopment. Cleanup standards have been made slightly more flexible, so that future commercial and industrial developments on brownfields do not need to be cleaned to pristine environmental standards. Such developments can be cleaned to a level where some pollutants may remain on site in such levels as to not pose a health risk to humans. In addition, several liability relief packages have been created to are target the redevelopment of sites in economically disadvantaged areas. In order to take advantage of these programs communities must be able to understand the physical and economic context of their contaminated properties. The potential use of the spatial analysis tools of GIS to aid in brownfield development has therefore grown as these programs have broadened in scope.

Cluster analysis can help identify areas where sites are more closely clustered together. Sites that lie in clusters may then be packaged together into one redevelopment area. This can make a brownfield site of large enough to make clean up costs more recoverable in reuse strategies by developers. A clustering of sites can also help a community focus larger comprehensive planning efforts in those areas to help foster their reuse.

Since more factors are being considered in brownfield redevelopment it encourages spatial analysis of data besides that pertaining to site contamination, history, and location. Land use data can be used to tackle brownfield sites as a land use planning issue. Communities could use GIS to analyze the land use surrounding their brownfield sites and recommend redevelopment proposals that were in keeping with their surrounding uses. With an idea of potential future uses of a sites, communities can find out if it qualifies for certain brownfield redevelopment programs. Other buffer analyses could be performed using GIS with economic data, to see if brownfield sites meet economic criteria that qualify them for special funds to induce development.

As brownfield redevelopment policy has broadened in scope so too has the potential use of GIS as tool to facilitate redevelopment. GIS can help communities better understand the extent of their brownfield problems, clear up some of confusion about these sites, and help determine whether sites qualify for certain brownfield programs. However, there exists no established framework in which to apply GIS in a brownfields context. We will now propose a methodology in which GIS can be applied to facilitate brownfield redevelopment.

Outlining a General Brownfields GIS Methodology

When building a GIS focused on brownfield redevelopment one must first obtain a map or list of contaminated properties either from the state or local authorities. Once the list is obtained one must determine which part of the brownfields challenge is going to be addressed as this will determine what local and state data sets are useful for the analysis. For instance, an analysis of the economic surroundings of sites will be quite different than a land use analysis in terms of the data and GIS capacities required. A combination of both state and local data should be obtained. State data can be most often used to create an overview of brownfield sites, while local data can refine and make the analysis using state data more detailed. For an analysis of economic conditions around sites, state economic data can provide an overview of the conditions, while local census or assessor's data can be used to add more detail to the analysis. Basically, data should be obtained that are relevant to the question being addressed.

Once the appropriate data are obtained for brownfield development they should be looked over and if necessary prepared for geo-referencing or cross-referencing. If a data set relating to brownfields is still tabular and not able to be mapped, it should first be checked for obvious errors that may affect the geo-referencing process. These errors can then be corrected to facilitate easier geo-referencing. If for instance a list of contaminated properties stores street address information in several fields, the data should be combined into one field. This would speed up geo-referencing as most facilities look for address information in one field only. Once all maps have been selected they should be checked to make sure they all use the same projection system. If a map does not use the same projection system as the others, it can quickly be converted to the appropriate one for spatial analysis. The maps should also all be in the same GIS format. Gradually, the large GIS vendors are providing "enterprise" GIS that allow basemaps to be accessed from shared file servers and converted as needed to particular map projections and levels of detail. Such developments make the data sharing and cross-referencing suggested here much more practical.

When the appropriate data sets have been obtained, spatial analysis with GIS can begin. First the appropriate analyses to perform and the GIS packages necessary to perform these analyses must be determined. If we are interested in clusters of sites, or of other data such as crime reports around them, we would perform a cluster analysis, and would need less advanced GIS capacities. However if we are more interested in seeing characteristics around the sites we would use a buffer analysis, that would require slightly more advanced GIS capacities. If we wished to determine whether brownfield sites were surrounded by more vacant parcels we would perform such an analysis by buffering the sites and then to looking at vacancy information in local assessor's data within and outside the buffer zones. The analysis can then be refined to address specific concerns raised from a preliminary assessment of the data.

The basic steps in using the existing GIS framework in brownfield development are as follows: identify of the aspect of brownfields to be studied, obtain a list of contaminated parcels, obtain appropriate state and local data, prepare data for geo-referencing and analysis, determine the type of analysis to be performed, and finally perform the analysis. This process can be considered a narrowing down approach for GIS use in brownfield redevelopment. It begins by using state data to analyze brownfields and then introduces local data or more state data to refine the analysis. As the approach relies on existing data, it avoids the costs associated with developing and acquiring data from scratch. Such an approach can help communities, neighborhoods, or economic agencies with limited funds and GIS capacities, such as a city economic development office or a community development corporation (CDC), use existing data to obtain a more complete understanding of their brownfield situation.

The next two chapters of this thesis will describe how this methodology can be used to develop a GIS focusing on brownfields, through a case study using Boston, and later the Codman Square Neighborhood Development Corporation's service area. Although the CSNDC does not have an in house GIS staff, both Massachusetts and the City of Boston, have several sets of data that can be of use in applying the narrowing down approach to an agency that is limited in what it can spend for brownfields analysis.

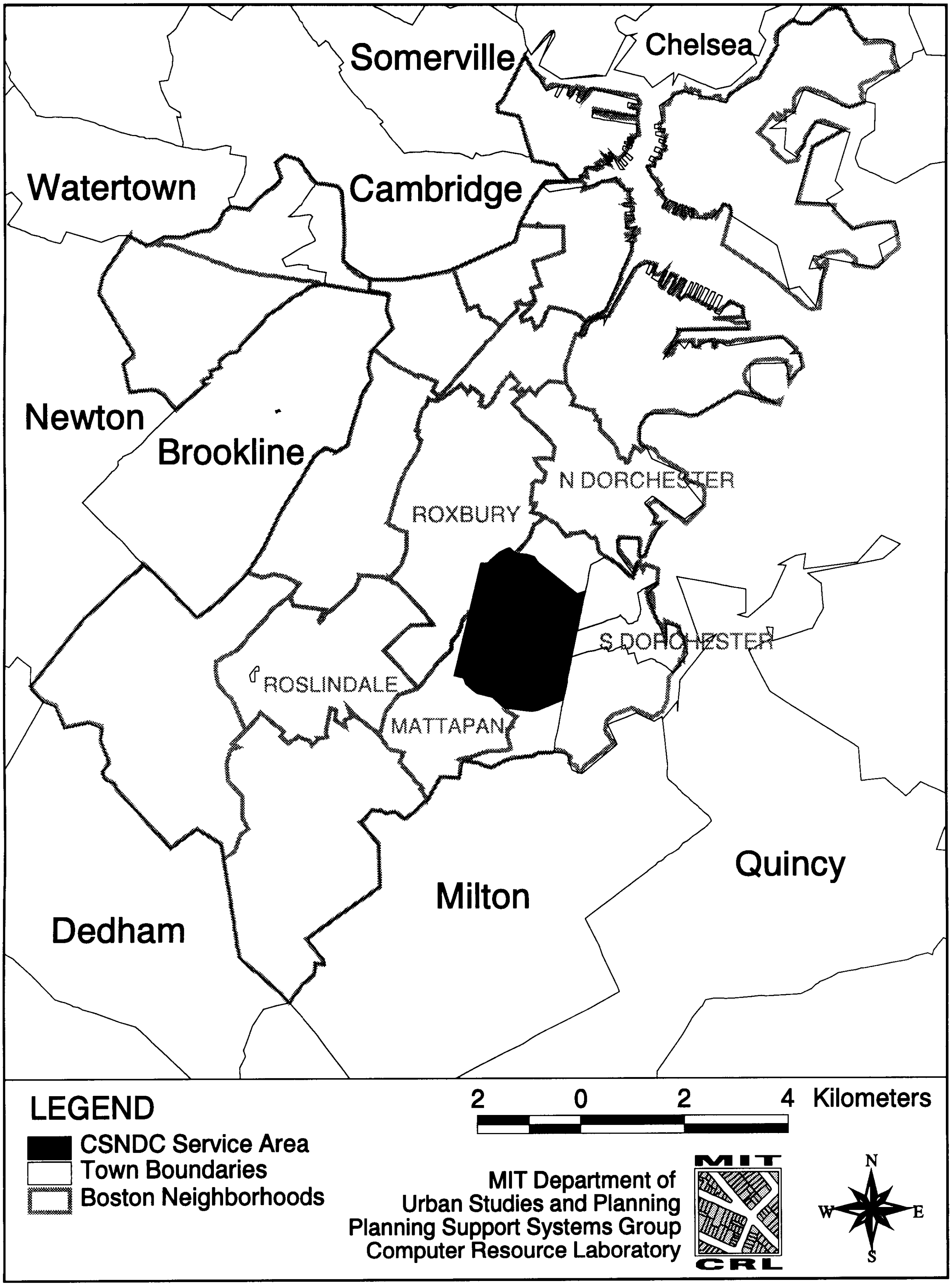
CHAPTER V: OBTAINING AND PREPARING BROWNFIELDS DATA

Sorting Through State and Local Data

Boston is the municipality with the largest number of contaminated properties according to the Massachusetts Department of Environmental Protection. Its location among its surrounding communities is illustrated in Figure 1 which also indicates the location of the service area of the Codman Square Neighborhood Development Corporation. Codman Square lies within Dorchester, a town that was annexed by the City of Boston in 1870, and is typical of many older neighborhoods of the city with a mix of commercial, industrial, and residential uses (See Figure 1for location). The CSNDC is one of the largest CDC's and its service area was chosen as a case study, since it is like many other neighborhood organizations that come across brownfield sites in its work, and a good amount of digital data existed that could be used for brownfields analysis. A problem that they have come across in many of their urban revitalization projects is the presence of confirmed or suspected contaminated properties. These sites are seen as a direct impediment to, and have frustrated many overall redevelopment strategies that have been developed by the CSNDC. The CSNDC is also representative of a city or neighborhood agency that can apply for federal brownfield pilot project funds. These local agencies are also the ones that most often come into contact with brownfields in their daily activities and could make the most use of a GIS relating to brownfields development.

Now that a study area has been selected the data relating to brownfields and the appropriate type of analysis to perform must be determined. Since the proposed changes to the Massachusetts Clean Sites Initiative and Chapter 21E would create flexible clean up standards for contaminated properties that depend on the ultimate use on a site, approaching brownfields as a land use planning issue can be useful. An analysis of land use around sites would enable the CSNDC to propose reuse strategies that were in keeping with surrounding uses of sites. With an understanding of what can be proposed, the CSNDC can determine if its brownfields qualify for certain programs or if they can be cleaned up to lower standards in the proposed legislation. This information can be obtained through a buffer analysis of land use data from the state or Boston, but before this analysis can occur we must obtain a list of brownfields in Boston and Codman Square.

Figure 1: Location of Boston and Codman Square



The provisions of Chapter 21E mandate that the state Department of Environmental Protection maintain and update yearly a list of sites that are contaminated or suspected to be so. There are two lists of sites, those reported to DEP prior to October 1993 and after 1993. Both lists are public information and can both be downloaded from the Department's World Wide Web site at *http://www.magnet.state.ma.us/dep/* and geo-referenced to map out the sites in Boston. In addition to being able to download this data from the site, users can also access rules and regulations pertaining to brownfields as well. It serves as a fast and efficient way to get the information to the public.

The two 21E site databases keep track of response actions pertaining to each spill that requires DEP notification according to MCP guidelines. Although many of the sites on the lists are no longer considered to be contaminated, as they have been cleaned to a response action outcome (RAO) according to the state, they were still contaminated at some point. Since the past legal framework made it difficult for owners of contaminated properties to clean them up, many owners did not report spills of hazardous or petroleum products on their property. As a result there may be more contaminated parcels out there that have not been reported. In the absence of an in depth survey of potentially contaminated sites, the two lists can be used as a starting point to identify brownfield sites. The land use characteristics of these parcels can be studied to identify others with similar uses, or surrounded by a similar mix of uses, that may be contaminated and warrant further study.

Those spills reported before October 1, 1993, when the latest revisions to Chapter 21E and the MCP took effect, are placed on the sites database, while those reported after that date are tracked in the release database. The structure for each database is different as funds were made available after October 1993 to correct problems with the earlier database design. The release database is more centralized, contains more tables, and has improved fields for recording the address and town of sites. Although the databases are designed differently both contain tables that list information pertaining to the original spill, all response actions that occur on a site, and the nature of the chemical spill.

However, the release database was not designed to accommodate certain information for sites reported after October 1993. In particular, the revisions require that if a site is not cleaned up to a RAO within a year after a spill is reported, it must receive a tier classification from DEP. The tier classification determines the level of the Department's oversight on the clean up action. A Tier I classification on a site indicates that DEP has direct oversight of the clean up operation, while a clean up operation on a Tier II site may occur without direct DEP supervision by a LSP. If a spill does not receive a RAO and is not given a tier classification within a year, that site is out of compliance with the MCP and Chapter 21E. The release database does not have a way to keep track of a site's tier classification status.

Generally a site will appear in only one of the databases according when DEP was notified of it. If a spill was reported to DEP before October 1, 1993 it is tracked in the sites database. All sites reported before that date were required to be tier classified as part of the transition plan for the 1993 MCP revisions. The site is placed in the sites table, and all subsequent actions taking place on that site are listed in the sactions table of the sites database. In general a reported after October 1993 will appear only in the release database and all site actions are tracked in the actions table in that database. However, those sites reported after 1993 that do not receive a RAO within a year are also recorded in the sites database as well. All further action taken on that site is then tracked in the sites database and not the release database. Therefore we can consider the list of sites on the sites database to be tiered sites, while those in the release database only are untiered sites.

The lists of tiered and untiered sites however are in tabular form and must be geo-referenced in order to be used in any spatial analysis. The geo-referencing will be described shortly. Besides the list of contaminated properties provided by the DEP, Massachusetts can provide us with useful land use data. The state land use coverage for Boston, which we will refer to as *bost-lu*, that is provided by MassGIS, can be utilized to perform a preliminary assessment of the land use characteristics of the mapped 21E sites in Boston. This coverage is very similar to other state land use coverages that have been developed by analyzing aerial images for larger land use patterns. As this coverage was not made from a land use survey, and is geared towards land use analyses of aquifers and other natural resources, it does not provide very detailed land use data. It can be used most effectively in an analysis of land use for all of Boston.

Fortunately land use data from the City of Boston's Assessor's Office were available and used, in addition to the *bost-lu* coverage, to perform a detailed land use analysis for the CSNDC. The assessor's data contains land use and land value information for each parcel in the city and is a rich source of data. Our land use analysis will begin with a buffer analysis for the whole city that uses the *bost-lu* coverage. This analysis will be refined for the CSNDC by using the detailed assessor's data in a buffer land use analysis. However we need to first geo-reference Boston's brownfields to perform this analysis.

Mapping Boston's Brownfields

Before the two lists of sites were geo-referenced, a quick look through the data indicated that the location of each site on the list was stored as a street address. It made sense to geo-reference the street address of each site using the street addresses stored in the Census Bureau's TIGER street files. As the *bost-lu* land use coverage, the City's assessor's data, and the TIGER line files were both in the NAD 83 square meters projection system, there was no difficulty in determining what projection system to use or in correcting for differences in the maps. MapInfo, a commonly used GIS package with a well developed interactive geo-referencing facility was used to geo-reference each list.

The sites that had Boston listed as their city were pulled from the sites and release databases in order to make two small and more manageable lists for geo-referencing. Boston had the most sites listed in each database, indicating it had the greatest amount of contaminated properties of any city in the state. There were 735 distinct site identification numbers listed for Boston in the sites database and 859 in the release database. Each site identification number represents an individual release of petroleum or hazardous materials. However, before the lists were geo-referenced it was discovered that the tiered sites listed in the sites database, recorded addresses for Boston in a way that could pose difficulties for the automatic geo-referencing process.

Because Boston annexed several municipalities in the late 1800's there exist several streets within the city boundaries with the same name. Therefore, the address field in the sites database attached a three letter tag at the end of each Boston address to indicate the area of the city where the site is located, which would be useful when duplicate matches were found. However, as the automatic geo-referencing facility looked for exact or very similar names, the tags posed a problem. To facilitate automatic geo-referencing, the tag was removed and placed in a new district field.[25] This field was then used in the interactive phase of geo-referencing to determine the correct locations of sites with multiple matches. The list of sites reported after 1993 had the neighborhood of the site already listed in a separate field and did not have to go through this process.

At the end of the interactive phase of geo-referencing 672 of the tiered 21E sites in the sites database were matched, resulting in a fairly high match rate of 91%. Further analysis revealed that there were only 635 distinct addresses for sites within Boston, indicating that multiple releases had been reported at individual addresses. When we look at the non-tiered sites we find 859 distinct site identification numbers in the Boston area in the release database. Of these, 125 have received a tier ranking and are duplicated in the sites database, meaning there are 734 untiered 21E sites within Boston. Of the untiered sites, 698 were mapped resulting in a 95% match rate for these sites.

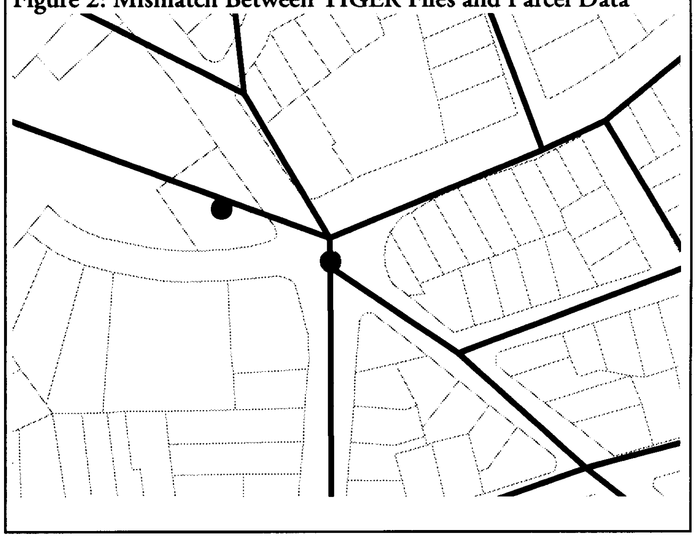
The resulting maps of tiered and untiered sites, each represented an individual site by a point. As the maps had been made by geo-referencing the lists using the TIGER files in the Massachusetts State Plane projection system, they could be used with the land use maps we had selected earlier. However, the maps were in MapInfo format and the land use maps were ArcInfo coverages, which is a format that is not supported by MapInfo. Since ArcInfo can also perform more complicated buffering and intersection operations, it was decided to convert the two maps of contaminated sites into ArcInfo coverages. Using a program called mifshape the MapInfo coverages

[25] Taking the code representing the area of the city off of the street addresses in the sites database took some time. Although it only took a short amount of time, it was a mindless and unneccessary task, even though it sped up the automatic geo-referencing process. Since Boston is one of the few cities and towns in Massachusetts that has annexed other towns, the data indicating which area of the city a street is located in needs to exist. If this neighborhood identifier in the sites database were stored in a separate column in the database of sites, then pulling off the neighborhood code could be avoided. Fortunately, the release database which is used to keep track of current releases already has this field separated from the street address and this list did not have to go through this additional prepartory step.

were first converted into ArcView shapefiles, which can be read by the GIS programs provided by the Environmental Systems Research Institute (ESRI), namely ArcInfo and ArcView.

Before we converted the shapefiles of tiered and untiered sites into an ArcInfo coverages, we drew each on top of the parcels coverage in ArcView to see if the points were located on top of the parcels they represented. The street address for each point representing a site was located and compared with the corresponding parcel. In most cases they did not match. Since the TIGER files were used in geo-referencing we drew that coverage on top of the parcels map to see if they lined up. Figure 2 indicates parcels by the thin grey lines while the TIGER files are represented as thick black lines. They did not line up, as most of the TIGER files did not fall within the voids on the parcel coverage that represented streets, making it no surprise that the two site coverages did not line up with the assessor's data. Figure 2 also highlights such a mismatch as the point representing the site was originally mapped far from its appropriate parcel. The mismatch caused a problem because the analysis of the assessor's data for the sites in Codman Square required the appropriate parcel data for each site be selected.

Figure 2: Mismatch Between TIGER Files and Parcel Data



As it is easier to edit a shapefile than an ArcInfo coverage, we decided to edit and save the two shapefiles containing the point coverage of address-matched sites to ameliorate this problem. The corrected files could then be converted into ArcInfo coverages. The street address of each site was compared to the street address of the parcel it was located on to see if they matched. If they did not match the point was moved so it was located on top of the parcel with the same street address. Each set of sites went through the procedure and the edited shapefiles were saved. Before we exited ArcView we selected two sets of parcels from the assessor's data which represent the tiered and untiered sites in Codman Square. This was done by selecting the parcels that completely contained a point representing each site, and saving the selected parcels as a shapefile for both the tiered and untiered sites.

The shapefiles representing the tiered and untiered sites were converted into ArcInfo coverages using the shapearc command in ArcInfo. The shapefiles representing the untiered and tiered parcels were also converted using the same command. Once this was done all the coverages we needed for spatial analysis were complete. The process of preparing the maps of sites for our land use analysis took a great deal of time. Although the state land use coverage and the assessor's data were both ready for analysis, the preparation of the maps of the tiered and untiered sites and parcels took the majority of this time. The main problems associated with these maps were the preparation of the addresses in the sites database for geo-referencing, interactive geo-referencing for both lists, and the editing of both maps to make them line up with the assessor's parcel level data.

The automatic geo-referencing went fairly quickly for both lists of sites and matched about 70% of all cases in both lists. Interactive geo-referencing took a good deal of time, about 6 hours for each database but raised the match rates for 91% for the tiered sites and 95% for the untiered sites. Since TIGER files keep track of numerical addresses, records with an institution name as an address were not able to be mapped by the automatic geo-referencing facilities in MapInfo. In particular, most of the spills reported in Logan Airport did not have a street address listed and were not matched at the end of interactive geo-referencing. However, most of these sites were later placed on the map by hand. Addresses that were referred to by a local name, were extremely poorly spelt, or were missing a address number were not able to be mapped.

Editing the shapefiles to match the sites to the appropriate parcels also took a great deal of time. The street addresses of sites could have been geo-referencing to the street addresses of the parcels in the assessor's data, but this would also create problems. First the street address information in the assessor's data was stored in two fields. This information would have to combined into one column for automatic and interactive geo-referencing, and this takes time. However, this is preferable to having two types of information in the same column as with the street address and neighborhood code in the sites database, as it is easier to concatenate data that to split it up. In addition there were many parcels in the assessor's data which did not have an address recorded. If the parcel on which a site was located did not have its address recorded then it would not be mapped.

The problems that were encountered were troublesome but not insurmountable. It took a good amount of patience to accomplish the geo-referencing, but it was finished and with a relatively high match rate percentage. There are several things can be done to improve the process which will be explained in detail in the conclusions to this thesis. By drawing both maps we can observe where the brownfield sites are located in Boston, and observe any large clustering of sites.

Preliminary Observations

After the geo-referencing was finished for the tiered and untiered sites, both sets of matched sites were indicated as points upon a map of Boston. Looking briefly at the maps (Figures 3 and 4), a few strong patterns emerge. The first that is noticeable in both sets is that the are sites are arranged in a pattern similar to a spider-web. Sites tend to follow the main commercial and heavily traveled roads in the city, the Washington Street running from Downtown Boston south to Dorchester reads quite well. There are also five readily visible clusters of sites, around North Station, around the Massachusetts Avenue/Southeast Expressway interchange, by Boston City Hospital, around the South Bay incinerator just south of Boston City Hospital, along Washington Street in Brighton, and in the Fenway area of Boston centered around Bolyston Street. In addition a great deal of sites exist in Logan Airport.

Figure 3: Map of Tiered Sites in Boston

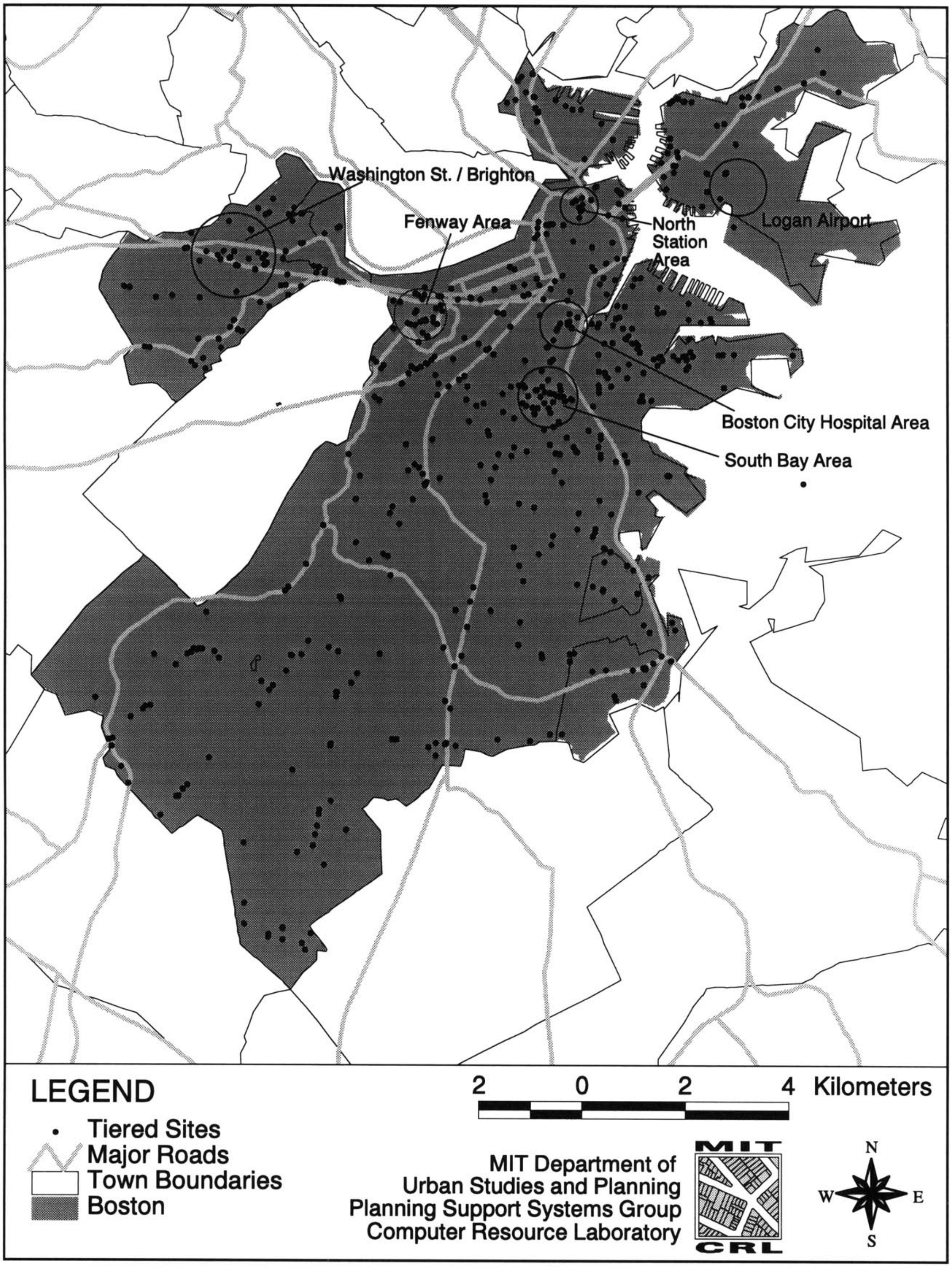
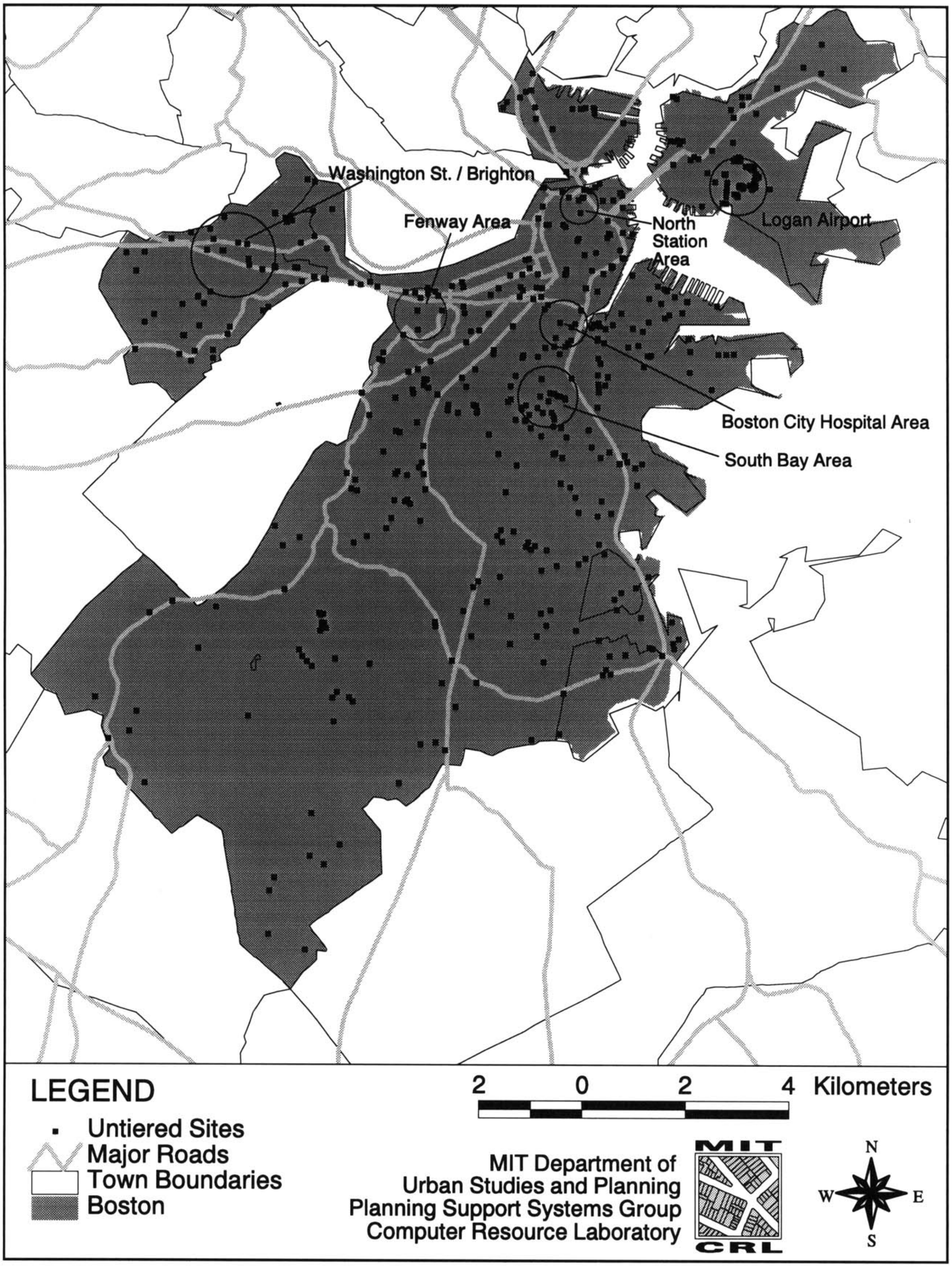


Figure 4: Map of Untiered Sites in Boston



CHAPTER VI: ANALYZING THE LAND USE CONTEXT OF BROWNFIELDS WITH GIS

Utilizing State Land Use Data

Since we are looking at the land use characteristics around brownfields in Boston and Codman Square, and as the data sets have all been prepared, they can be combined to can perform a land use analysis. A buffer analysis that compares the land uses within a buffer surrounding the sites to the patterns outside the buffer can help planners to better understand the extent to which the land use characteristics around these sites are different from across the city. These analyses can provide information to planners that can help them determine if commercial and industrial reuse strategies for these sites can be proposed, given their surrounding land uses. A series of buffers around the sites can allow planners to observe how land use characteristics around contaminated properties change as the distance from them increases. This can help planners to better understand how a community's character can change as the distance from the sites increases.

When a buffer analysis is used around brownfield sites there are many distances that can be used to represent different areas of interest. The buffer distance should be selected according to the level of analysis sought. A small buffer, such as 100 feet around the centroid of any given site in most cases will focus on that parcel and its immediate neighbors. To expand the scope of analysis to incorporate parcels beyond those immediately surrounding a site, such as parcels across the street from it, a buffer distance of about 300 feet is practical. Generally, as the buffer distance increases around any given site, the characteristics of the area included in analysis will more closely resemble those of the larger area of study.

While there is great flexibility in determining the buffer distance for most analyses relating to brownfields, in many cases this distance for some analyses will be prescribed or determined by a larger brownfield policy. Most states require that neighbors within a certain distance of certain types of chemical spills be notified about cleanup activities on that site. If that distance was 200 feet, a site meeting the appropriate criteria could be mapped and the appropriate neighbors notified. Most land use buffer analyses do not have any prescribed buffer distances, which can provide great latitude in selecting an appropriate buffer distance.

To determine the buffer distance for our land use analysis we determined the average perimeter for a block in Boston and a parcel in Codman Square which were both divided by four to determine the average length of a block and parcel respectively. We could buffer by these amounts, to look at the land use in the parcels immediately surrounding the sites and in the block as well. The block calculations revealed that the average perimeter of a block in Boston is 1102.53 meters, which results in an average block length of 273.63 meters. The average parcel in Codman Square had a perimeter of 115.30 meters and an average length of 28.83 meters, and the number varied slightly for each type of land use. The average perimeter of a commercial or industrial parcel was 116.45 meters, resulting in an average parcel length of 29.11 meters. For exempt properties the average perimeter is 178.21 meters with an average parcel length of 44.55 meters. Residential parcels have an average perimeter of 112.52 meters and an average length of 28.13 meters.

As a result of these calculations each tiered and untiered site in Boston was buffered from its centroid by 100 meters, or about 300 feet. This distance can allow the land use on a site and the parcels immediately surrounding it to be analyzed. Each site was also buffered by 250 meters, or a roughly 750 feet, buffer. This distance can allow the land use in the block surrounding a site to be analyzed. In addition, the larger buffer can be used to observe how the land use characteristics around the sites changes as the distance from them increases. In our study, the areas within the 100 meter buffer of both the tiered and untiered sites represented approximately 10% of the City's area. When the buffer was increased to 250 meters, this percentage rose to approximately 41% for each coverage (See Table 3).

The coverages of tiered and untiered sites were buffered using the buffer command in ArcInfo to create two buffer coverages for each set. These coverages were then intersected with the bost-lu coverage with the clip command in ArcInfo to obtain the land use characteristics for the area within each buffer. The land use characteristics within each buffer were then be compared to those in the other buffers and to the land use characteristics for the whole City. Although it may have made sense to combine both lists of sites into one coverage of contaminated properties, the untiered and tiered 21E sites were mapped and buffered separately to indicate the difference between the sites and because of the differences between the two databases.

Comparison of Uses Between Buffered Areas

As a first analysis, the percentages of each type of land use, as classified in the bost-lu coverage, within each set of buffers were compared to the percentages for the whole city. This type of analysis can illustrate , say, whether or not the 21E sites in Boston are more likely to be surrounded by more commercial and industrial land uses than what would be expected from looking at the percentages for the whole city. The results in Table 1 indicate that in the City of Boston 32% of the acres in the city are classified as small lot residential, while 10% are commercial, 12% are urban open, 11% are transportation, and 3.6% of the lands are classified as Industrial

Table 1 lists the land uses by their percentages in the whole City of Boston in declining order. If the brownfield sites are located in areas representative of the entire city the percentages should remain about the same regardless of buffer size. However, a look at Table 1 indicates the sites in Boston are not in areas representative of the entire city. In particular the percentage of commercial area within both buffers, 33.33% for the tiered sites and 27.80% for the untiered sites, are approximately three times as large as the 10.46% calculated for the city. Industrial lands comprise 7.86% of the area within the 100 meter buffer of tiered sites, and 6.55% within the buffer of untiered sites. These percentages are approximately double the 3.59% calculated for the City.

A look at Table 1 also highlights strong patterns in residential use between the buffered areas and the rest of the City. 11.76% of the area within the 100 meter buffer of the tiered sites, and 11.15% of the area within the buffer of the untiered sites, is multifamily residential while this percentage is only 8.62% for the entire City. While these percentages are higher than those calculated for all of Boston, there appears to be less small lot residential areas within the 100 meter buffers.

Table 1: Percentages of Acres Within Boston and the 100 Meter Buffers

Land use	Boston Total Acres	Percentage of Total Acreage	Percentage of Tiered Acres	Percentage of Non-Tiered Acres
Small Lot Residential	10228.6890	32.24	19.30	21.647
Urban Open	3870.3140	12.20	9.72	9.879
Transportation	3801.4410	11.98	11.91	15.904
Commercial	3319.8960	10.46	33.33	27.803
Multi-Family Residential	2736.0220	8.62	11.76	11.146
Forest	2116.8140	6.67	1.31	1.443
Spectator Recreation	1260.9270	3.97	2.05	2.084
Industrial	1138.9660	3.59	7.86	6.552
Open Land	676.1580	2.13	0.50	1.008
Participation Recreation	650.7240	2.05	0.69	0.432
Water	550.1780	1.73	0.11	0.588
Wetland	293.5900	0.93	0.31	0.286
Medium Lot Residential	249.3860	0.79	0.33	0.282
Waste Disposal	203.2520	0.64	0.42	0.421
Woody Perennial	180.8350	0.57	0.13	
Salt Wetland	147.7780	0.47	0.00	0.137
Water-Based Recreation	106.6900	0.34	0.28	0.277
Mining	61.4590	0.19		
Large Lot Residential	58.4150	0.18		
Pasture	43.9120	0.14		0.109
Cropland	27.5320	0.09		

While small lot residential lands account for 32.24% of the City's area only 19.30% of the area within the buffer of the tiered sites, and 21.65% of the area within 100 meters of the untiered sites, is small lot residential. Both percentages represent drops of more than 10% from the number calculated for the entire City. These numbers indicate that the areas immediately surrounding the sites tend to be surrounded by more commercial and industrial lands and do not have as great a concentration of small lot residential lands than the rest of the city.

Table 2 lists the percentage of acres in Boston that are contained within the two 250 meter buffered coverages, by land use. Looking the numbers over, we see that the percentage of commercial and industrial lands within the buffered areas coverages begin to fall, but are still larger than the corresponding percentages for the whole city. In the area within the buffer around the tiered sites, 20% of the lands were classified as commercial while 5.8% were industrial. In the buffer around the untiered sites 20.3% of the land was classified as commercial, while 5.6% were industrial. In both instances the percentages are higher than the 10% and 3.6% calculated for commercial and industrial areas in Boston.

Table 2: Percentages of Acres Within Boston and the 250 Meter Buffers

Land use	Boston Total Acres	Percentage of Total Acreage	Percentage of Tiered Acres	Percentage of Non-Tiered Acres
Small Lot Residential	10228.6890	32.241	27.76	27.00
Urban Open	3870.3140	12.199	10.74	11.11
Transportation	3801.4410	11.982	11.97	13.98
Commercial	3319.8960	10.464	20.14	20.29
Multi-Family Residential	2736.0220	8.624	13.21	11.74
Forest	2116.8140	6.672	1.93	2.11
Spectator Recreation	1260.9270	3.974	3.75	3.10
Industrial	1138.9660	3.590	5.81	5.59
Open Land	676.1580	2.131	0.92	0.99
Participation Recreation	650.7240	2.051	1.03	0.88
Water	550.1780	1.734	0.67	1.46
Wetland	293.5900	0.925	0.34	0.26
Medium Lot Residential	249.3860	0.786	0.60	0.40
Waste Disposal	203.2520	0.641	0.39	0.47
Woody Perennial	180.8350	0.570	0.36	0.06
Salt Wetland	147.7780	0.466	0.06	0.15
Water-Based Recreation	106.6900	0.336	0.31	0.22
Mining	61.4590	0.194		
Large Lot Residential	58.4150	0.184		
Pasture	43.9120	0.138	0.00	0.14
Cropland	27.5320	0.087		0.03

For residential uses, within the 250 meter buffer of the tiered sites, 13.2% of the area was classified as multi-family residential and 27.8% was classified as small-lot residential. These numbers represent increases of 1.5% and 8.5% respectively over the values calculated for the area within the 100 meter buffer. The results for the areas within the 250 meter buffer of the untiered sites are also similar. 11.7% of the area is classified as multi-family residential while 27% is classified as small lot residential. These values are increases of .6% and 5.4% from the values calculated from within the 100 meter buffer.

These numbers indicate that the areas closely surrounding 21E sites tend to be considerably more industrial and commercial, have somewhat more multifamily dwellings, and considerably less small lot residential areas than the rest of the city. As we move farther away from the sites the concentration of commercial and industrial lands tends to decrease while the amount of small lot residential lands increases.

Percentage of Land Use Totals Within Buffered Areas

Another way of looking at the same issue, of whether brownfield sites in Boston are more likely to be located within commercial and industrial areas, is whether or not the 21E sites are disproportionally located within these commercial and industrial areas. This analysis can be done by comparing the area of each land classification within the buffers to the area of the same classification within the whole city. This will reveal what percentage of each land use type within Boston lies in the buffered areas. If no disproportionality is present we would expect these percentages to be similar to the percentage representing the percentage of the buffer's total area to the total amount of land in Boston.

Table 3: Buffered Areas as a Percentage of Boston's Total Area

	Acres in 100 meter buffer	100m Buffers as Percentage of Acres in Boston	Acres in 250 meter buffer	250m Buffers as Percentage of Acres in Boston
Tiered Sites	3579.48	11.28	13735.97	43.30
Untiered Sites	3154.41	9.94	12518.03	39.46

Total Acres in Boston 31726.015

The area within the 100 meter buffer of tier classified sites represents 11.28% of Boston's total area, while for the sites without a tier classification the percentage is 9.94%. As the buffer distance around the two data sets increases to 250 meters, we find that the areas around the tier classified and non-tier classified sites represent 43.30% and 39.46% of Boston's area respectively.

The acres of each land use in the buffered areas was divided by the total number of acres within Boston to determine what percentage of acres of each land use lied within the buffered areas. Table 4 presents the results of this analysis for the 100 meter buffered areas. The table shows that of the non-residential uses 35.86% of Boston's commercially classified lands were within the 100 meter buffer of the tiered sites, while 24.65% of the City's industrial lands were located within the same area. Within the 100 meter buffer around sites without tier classifications, these percentages were 26.48% for commercial lands and 18.15% for industrial lands. As these percentages are substantially above those representing the percentage of the City's total area within the buffered areas, 11.28% and 9.94 for the tiered and untiered sites respectively, it indicates that Boston's 21E sites are disproportionally located in commercial and industrial areas.

Table 4: Acres of Land Use in the 100 Meter Buffers

Land use	Acres of Land Use in Boston	Percent of Land use in Boston	Acres in 100m Buffer of Tiered Sites	Acres in 100m Buffer of Tiered Sites as Percent of Boston Acres	Acres in 100m Buffer of Untiered Sites	Acres in 100m Buffer of Untiered Sites as Percent of Boston Acres
Small Lot Residential	10228.6890	32.241	689.40	6.74	682.84	6.68
Urban Open	3870.3140	12.199	347.25	8.97	311.65	8.05
Transportation	3801.4410	11.982	425.50	11.19	501.70	13.20
Commercial	3319.8960	10.464	1190.44	35.86	877.04	26.42
Multi-Family Residential	2736.0220	8.624	420.16	15.36	351.59	12.85
Forest	2116.8140	6.672	46.85	2.21	45.53	2.15
Spectator Recreation	1260.9270	3.974	73.19	5.80	65.72	5.21
Industrial	1138.9660	3.590	280.73	24.65	206.67	18.15
Open Land	676.1580	2.131	17.70	2.62	31.80	4.70
Participation Recreation	650.7240	2.051	24.55	3.77	13.63	2.09
Water	550.1780	1.734	3.86	0.70	18.55	3.37
Wetland	293.5900	0.925	11.04	3.76	9.01	3.07
Medium Lot Residential	249.3860	0.786	11.83	4.74	8.90	3.57
Waste Disposal	203.2520	0.641	14.83	7.30	13.28	6.53
Woody Perennial	180.8350	0.570	4.53	2.51		
Salt Wetland	147.7780	0.466	0.03	0.02	4.32	2.92
Water-Based Recreation	106.6900	0.336	10.01	9.38	8.73	8.18
Mining	61.4590	0.194				
Pasture	43.9120	0.184			3.45	7.87
Cropland	27.5320	0.138				
Large Lot Residential	27.5320	0.087				

Conversely, there is a disproportionate lack of small lot residential properties nearby these sites. Only 6.74% of the Boston's small lot residential lands and 15.36% of its multifamily lands lie within 100 meters of the tier classified sites. Within the 100 meter buffer of non-tier classified sites, the percentages are 6.67% for small lot residential and 12.85% for multifamily lands. Looking at the percentage of Boston's area that lies within the two buffers, 11.28% and 9.94% for tier classified and non-tier classified sites respectively, we see that there are less residential lands near the sites, but somewhat more multifamily housing than one would expect.

Table 5: Acres of Land Use in the 250 Meter Buffers

Land use	Acres of Land use in Boston	Percent of Land use in Boston	Acres in 250m Buffer of Tiered Sites	Acres in 250m Buffer of Tiered Sites as Percent of Boston Acres	Acres in 250m Buffer of Untiered Sites	Acres in 250m Buffer of Untiered Sites as Percent of Boston Acres
Small Lot Residential	10228.6890	32.24	689.40	6.74	3785.38	37.01
Urban Open	3870.3140	12.20	347.25	8.97	1464.15	37.83
Transportation	3801.4410	11.98	425.50	11.19	1633.06	42.96
Commercial	3319.8960	10.46	1190.44	35.86	2746.13	82.72
Multi-Family Residential	2736.0220	8.62	420.16	15.36	1802.06	65.86
Forest	2116.8140	6.67	46.85	2.21	263.18	12.43
Spectator Recreation	1260.9270	3.97	73.19	5.80	511.08	40.53
Industrial	1138.9660	3.59	280.73	24.65	792.48	69.58
Open Land	676.1580	2.13	17.70	2.62	125.62	18.58
Participation Recreation	650.7240	2.05	24.55	3.77	140.22	21.55
Water	550.1780	1.73	3.86	0.70	91.21	16.58
Wetland	293.5900	0.93	11.04	3.76	45.84	15.61
Medium Lot Residential	249.3860	0.79	11.83	4.74	82.03	32.89
Waste Disposal	203.2520	0.64	14.83	7.30	53.85	26.50
Woody Perennial	180.8350	0.57	4.53	2.51	49.26	27.24
Salt Wetland	147.7780	0.47	0.03	0.02	8.56	5.79
Water-Based Recreation	106.6900	0.34	10.01	9.38	42.74	40.06
Mining	61.4590	0.19				
Large Lot Residential	58.4150	0.18				
Pasture	43.9120	0.14			0.32	0.72
Cropland	27.5320	0.09				

The larger buffer area, like the smaller one, appears to have a disproportionate amount of lands designated as multifamily residential with Boston (see Table 5). The 250 meter buffer of the tier classified sites contains 65.86% of the city's multifamily residential lands although the buffer only represents 43.30% of the city's area. The buffer around sites without a tier classification contains 53.71% of Boston's multi-family residential lands, while it only represents 39.46% of the city. Despite the earlier profound lack of small lot residential uses within the 100 meter buffers, it has become much less pronounced in the larger buffer area. 37% of the Boston's small lot residential lands lie within the buffer around the tier classified sites, and a similar number of 33.04% exists within the same distance of the non-tier classified sites.

This analysis has shown that while the areas surrounding brownfield sites tend to be more commercial and industrial than for the rest of Boston, the sites themselves are also disproportionally located within these areas. The areas surrounding the sites also tend to have more multifamily residential uses and are disproportionally located in these areas as well. Although there is a lack of small lot residential use in close proximity to brownfield sites some is still located nearby them. The amount of small lot residential use increases as you move away from them, and the percentage falls more back in line with that calculated for the whole city by the time the buffer distance is increased to 250 meters. These findings are in keeping with the general view of brownfields as commercial and industrial properties. These preliminary findings would suggest that redeveloping the sites for commercial and industrial uses would complement surrounding land use patterns. The use of more detailed land use data can help refine the analysis to reinforce or disprove this statement.

6.2 Narrowing the Scope and Refining the Analysis

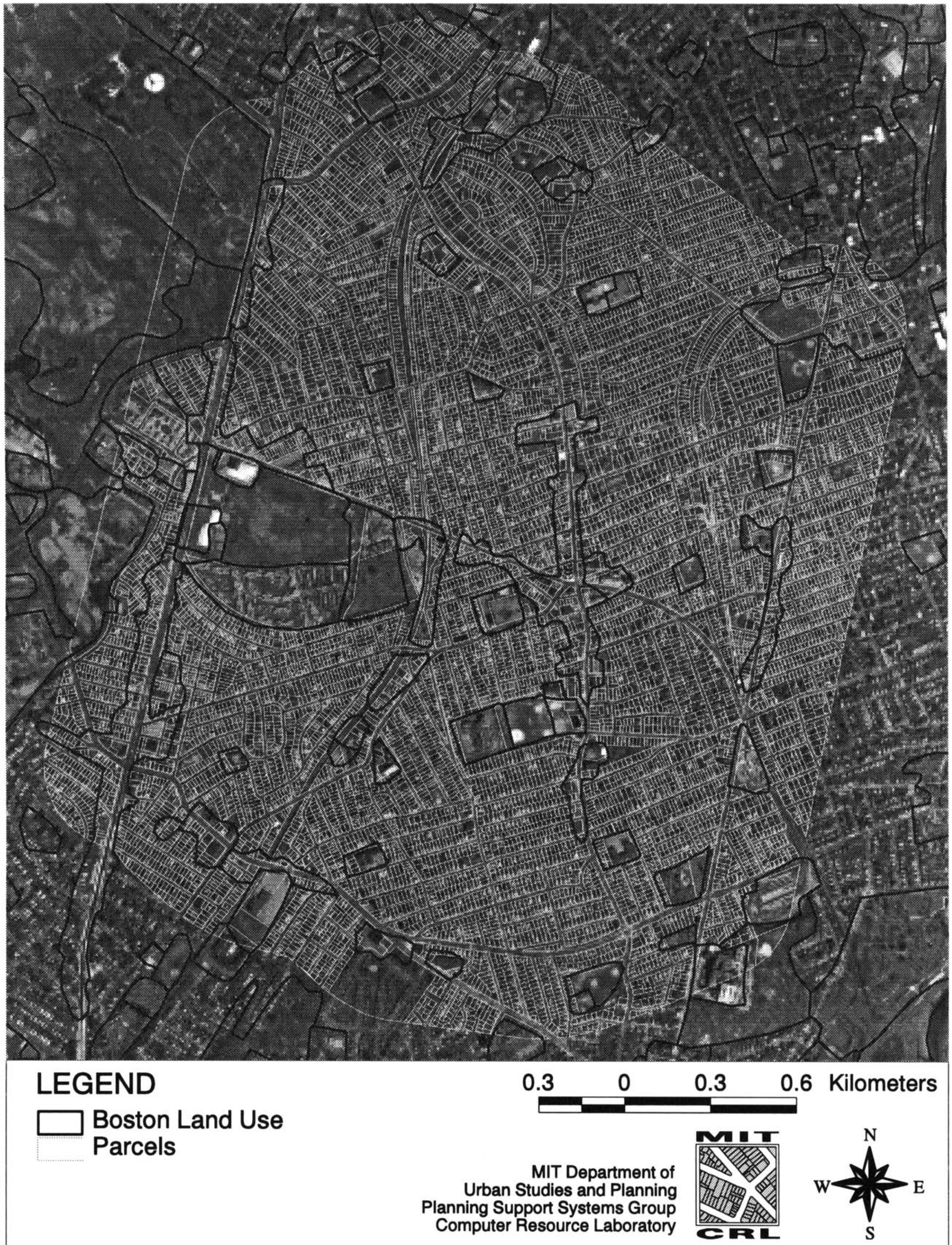
The buffer analysis using land use data provided by MassGIS has been useful in assessing broad questions relating to the land use characteristics around brownfield sites. However, the land use coverage provided by MassGIS is limited in the amount of information it can provide. As the coverage was developed from analysis of aerial photos by landscape architects it aggregates land uses into large geographic areas. As it was not developed through a survey process, it can not pick up the subtle parcel by parcel differences in land use that are important when dealing with brownfield redevelopment on the community or neighborhood level.

An area that is actually made up of a large mixture of uses will most likely be represented as the one type that dominates the others. A land use analysis using a state coverage can then make the area appear more uniform that it is in actuality. If a land use analysis of such a brownfield site were done using the state land use coverage, the actual diversity of uses around it would not be identified. If there were residential properties nearby a site, they may not appear in a state coverage if they were located in an otherwise commercial area. If a landowner were required to notify all surrounding residents in a surrounding area about clean up activities or a release of hazardous material, they may not fully identify all of them. This can lead to them not being notified and the site owner would have violated the law. Since a land use analysis can be used to help propose redevelopment strategies on brownfield sites that reflect surrounding land use characteristics, the use of the state coverage will not reflect the actual diversity of uses around a site. This in turn can limit how the site is viewed and many proposed site strategies.

Therefore the assessor's data from the City of Boston can provide a detailed land use data source that can be used to refine our analysis. As it contains information for each parcel in the city, parcel by parcel differences can be observed. The coverage for the whole city contains over 130,000 records that represent individual parcels. If we were to analyze the data for the whole city, parcel by parcel differences would not be able to be clearly observed due to the large amount of parcels that would be involved. In addition because of the amount of records for the entire city, calculations using the data for the whole City would take a great deal of time.

Figure 5 highlights the differences in the detail of data provided by the assessor's data for the parcels within 1,000 feet of the Codman Square Neighborhood Development Corporation. The parcel data and the state land use coverage are both drawn above a digital orthophoto for the area. Orthophotos are a good source of geographic information that can be used to more accurately represent the spatial context of an area and can be used to identify fetures on parcels such as houses that some coverages may not represent. As the two coverages show, the parcel data is much more detailed as land use is recorded for each parcel, whereas the state land use coverage groups land use by similar easily observable features.

Figure 5: An Overlay of State Land Use Data, Local Assessor's Data, and a Digital Orthophoto



The selection of a smaller focus of a neighborhood or area within the city can allow parcel by parcel differences in the data to be better observed. In addition it would greatly speed up data calculations if these parcels could be selected and stored as another coverage as there would be less records of data in the coverage. The analysis in this thesis then focused in on the service area of the Codman Square Neighborhood Development Corporation so the land use data could be used more effectively. Codman Square is typical of many older neighborhoods in the City of Boston as discussed earlier in this thesis. The CSNDC is also typical of many other neighborhood agencies that come across brownfields in their work. The location of the CSNDC is illustrated in Figure 1.

Since some brownfield sites were located on the edge of the service area (See Figure 6), if they were buffered and intersected with the parcels within the CSNDC's service area, the buffer analysis would be not be complete. When the buffer around such a site were intersected with the parcels coverage it would not select all the parcels within it. The buffer would only select those parcels that were within the CSNDC boundary and the resulting set of parcels would look like half a pie, rather than a full pie. Therefore we used a coverage of parcels within 1,000 foot buffer of this area as our base map of assessor's data to accommodate a buffer analysis of sites near the CSNDC's service area boundary. The 11,482 parcels within a 1,000 foot buffer of the CSNDC's service area comprise 8.32% of the 138,001 parcels within Boston. These parcels comprise 8.49% of the city's total lot area. Figure 7 is a map of the sites within Codman Square. It also illustrates the size of the buffer distances used in the analysis for the tiered sites.

Figure 6: A Site with Buffers at the Edge of the CSNDC's Service Area

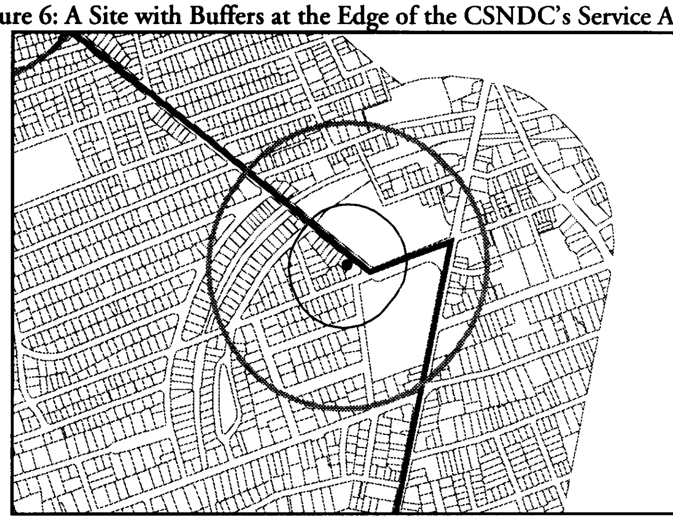
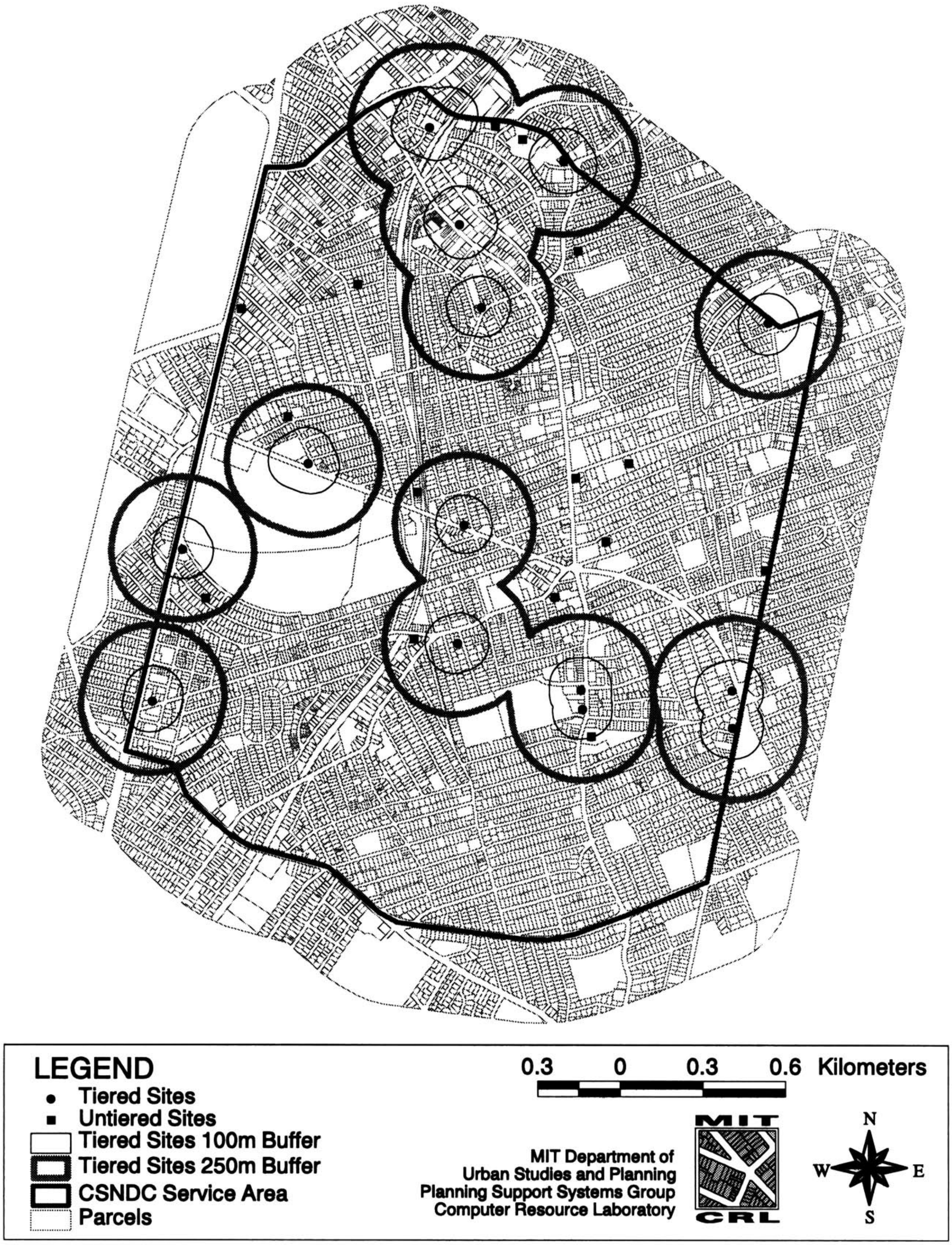


Figure 7: Location of 21E Sites in Codman Square



Analysis of the Assessor's Data for Codman Square

As in the other analysis, each set of sites was surrounded by a 100 meter and a 250 meter buffer. However, in this case the two coverages of tiered and untiered sites we created in ArcView were used in the buffering. These buffers were then intersected with the assessor's data using the clip command in ArcInfo to obtain the parcels touching, either in or clipped by each buffer. The parcel data for all of Boston, the CSNDC's service area, both sets of brownfield parcels within Codman Square, and the buffered areas were then analyzed using the Oracle SQL*Plus package to take advantage of that program's advanced analysis functions. In order to use Oracle, the data from each coverage was exported from ArcInfo using the infodbms into that program.

Before the assessor's data was analyzed to refine our earlier land use analysis, the information it contained on lot size and property value were analyzed. This analysis was done to determine the approximate size and value of existing brownfield sites. These values can be compared to the values computed for all parcels in Boston, those in Codman Square and the two sets of brownfield parcels to determine if the brownfield parcels in Codman Square have different values than the City of Boston. With a knowledge of the lot size and property values of these existing brownfield sites, other potentially contaminated parcels with similar characteristics could be identified.

These values can be presented as medians, averages, or in other ways. Averages are the most common way of summarizing information, though they can be unduly influenced by the presence of outliers or extreme values which can skew the results in their direction. Medians indicate the center value of the data when it is placed in an ordered list and give a measure of central tendancy that is less influenced by outliers. In a thorough investigation of the data a variety of these summary statistics would be used to analyze the data. If the data is just being used to obtain a basic understanding of an area, or if the tools for other summary statistics are unavailable, only one measure is often used. In the analysis of the assessor's data for Codman Square only averages were computed since Oracle SQL*Plus can not readily calculate medians and other summary statistics. In addition, averages are the most easily understood and used type of central tendancy measure.

The average size of a parcel within Boston is 12,062 square feet, or slightly more than a quarter acre. The same average parcel will have a land value of $121,418.69 dollars or $43.46 per square foot, a building value of $219,475.69, and a total value of $340,890.77. When we look at Codman Square these numbers are below the averages for the whole city, which indicates the area may be poorer than the city on a whole, be more densely developed, or have a different mix of land uses. Further analysis, which was not performed for this thesis, is required to help answer this question. The average size of a parcel in the service area of the CSNDC is 8,995 square feet, with a much lower average land value of $65,335.81 or $8.70 per square foot, and an average building value of $106,593.73, for an average total value of $171,929.55.

Table 6: Average Values for Boston, Codman Square, and 21E Parcels

	Average Lotsize (sqft)	Average Land Value	Average Building Value	Average Total Value	Average Land Value ($/sqft)
Boston	12,062	$121,418.69	$219,475.69	$340,890.77	$43.46
Codman Square + 1000m	8,995	$65,335.81	$106,593.73	$171,929.55	$8.70
Tiered Sites	10,273	$40,700.00	$46,161.54	$86,861.54	$6.06
Untiered Sites	23,327	$121,906.67	$181,986.67	$303,893.33	$7.09

Given the lower average values for the average parcel in Codman Square to begin with, we would expect the average land values for the contaminated properties to be even lower. Although the average size of the tier classified and non-tier classified sites are higher, 10,273 and 23,327 feet respectively, the two sets of sites exhibit different patterns with land values. The average values for tier classified parcels are lower than those for Codman Square, while the values for non-tiered sites, with the very notable exception of value per foot, are higher than the Codman Square averages. The average land value for the untiered parcels is $121,906.67 or $7.09 per square foot, while the average building value is $181,986.67, and the average total value is $303,893.33.

The difference in parcel size and building value raises questions about the use of averages especially when land value per square foot values are so similar. This gives some indication of the need to look at more than averages and other summary statistics, such as medians, or outliers in the data. The small amount of records for untiered parcels makes it easier for a parcel to skew these averages if it has a much higher or lower value than the other values. In our case, from the 11,482 parcels in the 1,000 foot buffer of Codman Square only 15 are on the untiered list and represent .1% of these parcels.

Since Oracle SQL*Plus does not readily perform medians, we will look at the average values by land use to look for the presence of possible outliers. The assessor's data gives each parcel a numerical code, referred to as stateclass, indicating the specific use on a site. These numbers can then be aggregated to form a variety of land use classification schemes. There are two schemes that can be readily used for the data. The assessors' data contains a field called land use which assigns each stateclass code into one of 13 categories. The stateclass code can also be grouped into one of 16 state land use codes by using a series of lookup tables to determine which category a particular stateclass code belongs.

Table 7: Average Values by Land Use: Boston Parcels

Landuse	Parcels	Average Lotsize (sqft)	Average Land Value	Average Building Value	Average by Square Foot Land Value ($/sqft)	Average Land Value (Total Land Value/ Total Area
Commercial	295	18,059	$556,739.34	$1,423,678.39	$673.86	$29.57
Commercial Land	4,879	11,060	$87,029.55	$11,930.30	$13.64	$7.55
Industrial	1,427	41,676	$303,816.70	$495,551.82	$12.73	$7.07
Total Comm/Industrial	6,601	20,034	$358,787.69	$798,187.79	$340.21	$17.21
Exempt	5,787	104,596	$726,843.12	$1,130,962.92	$20.66	$6.88
Exempt - 121A	473	23,293	$527,099.35	$2,521,378.74	$26.13	$22.20
Total Exempt	6,260	98,334	$711,597.26	$1,237,089.29	$21.08	$7.16
Apartments	2,181	13,722	$220,170.23	$607,043.84	$44.95	$15.85
Condoninum	39,836	8,424	$186.39	$56,016.17	$0.17	$0.02
Single Family Housing	29,444	5,159	$65,143.45	$78,342.55	$20.92	$12.63
Two Family Housing	18,513	4,879	$62,753.23	$89,265.85	$18.72	$12.86
Three Family Housing	15,988	3,635	$56,365.42	$89,504.58	$21.98	$15.51
Small Apartment House	3,126	3,645	$70,225.16	$177,078.54	$33.32	$19.23
Residential Multi-Use	2,406	5,044	$136,279.95	$407,831.22	$38.66	$26.46
Residential Land	11,365	6,071	$11,269.68	$377.61	$2.60	$1.86
Total Residential	122,859	5,233	$59,167.84	$97,221.99	$18.89	$11.30

We will first look at the average values by land use using the system based on the landuse field because it more clearly identifies different types of residential use, which is desirable due to the large amount of residential land in Boston. The values computed for Boston can then be compared them to those calculated for the parcels within a 1,000 foot buffer of the CSNDC's service area. We will then look at the parcel data for the untiered sites to look for possible outliers. The results of this analysis for Boston is listed in Table 7 while the results of the analysis of parcels in the 1,000 foot buffer of the CSNDC's service area are listed in Table 8. The results of the analysis for the non-tiered parcels in Codman Square are listed in Table 9.

Comparing the averages values between Boston and Codman Square we notice that the average values in most cases are lower. In particular the values for commercial and industrial parcels are substantially lower. While average lot size for a commercial/industrial parcel in Boston is 20,034 square feet, the average for the Codman Square parcels is almost half that size at 10,426 feet. Most striking are the differences in land values for commercial and industrial properties. In Boston the average commercial/industrial parcel will have an average land value of $358,787.69 or $340.21 per square foot. In Codman Square the average per square foot land value is $51,043 or $5.84 per square foot. In particular for commercial parcels only in Codman Square the average land value drops to $60,727.12 or $7.00 per square foot while these values are $556,739.34 and $673.86 for Boston respectively.

The values calculated for exempt parcels in Codman square are similar to those calculated for Boston with the exception of the average per square foot land value. In Codman Square this value is $6.08 per square foot while it is $21.08 for all of Boston. The values for residential uses, like those for commercial uses are less than those calculated for Boston. It should also be noted that the range of variation in the Codman Square values is less than that in the Boston parcels. These figures indicate the Codman Square area is more uniform in its land values than the rest of the City, and may be more economically disadvantaged as well. The sharp contrast in commercial land value indicates that another measure of average land value could be of assistance.

Table 7 lists two ways of calculating average land value. The first column of data, which has been used to describe average land value so far was computed by averaging the ratio of land value to lot size from each parcel. The second method was computed as a ratio of overall averages, and is listed in the last column in the table. In this case the total of land value for each type of land use in the city was divided by the total of lot size. The first method is an average of ratios and the second is a ratio of averages. Both methods are useful, but the first can end up being weighted by ratios that may be outliers. In Boston it appears as if some very expensive commercial properties with a high per foot land value might have pushed the calculated average land value upwards.

This is not a problem with the data, rather it indicates the usefulness of local data to catergorize land value and land use. Since local data is more detailed it is more sensitive to how calculations are performed. A glance at the second land value column in table 7 shows that the average values for Boston calculated as a ratio of averages in the second method, are lower for all land uses than those computed in the other method. Returning to Table 7 the average value of $29.57 per foot for commercial parcels, calculated as a ratio of averages for Boston is still higher than the $7.00 calculated in the old method in Codman Square.

Since the average per foot land values are lower for all types of parcels in Codman Square than the values computed by either method for Boston, it indicates that the Codman Square area may be more economically disadvantaged than other areas in Boston. In particular the average per foot value of commercial properties is of concern. The lower values can affect the ability to attract commercial development in the area, as investors need to be able to make a return on improvements. This may be difficult for development on parcels with overall lower land values. The lower average land values computed as averages of ratios for Codman Square indicate an analysis of land value in Codman Square using this method is less likely to be influenced by outliers. As a result this method is used to calculate average per square foot land value throughout the rest of this thesis as its focus soon shifts to an analysis of sites within Codman Square.

Table 8: Average Values by Land Use: Codman Square Parcels

Land use	Parcels	Average Lotsize (sqft)	Average Land Value	Average Building Value	Average Land Value ($/sqft)
Commercial	295	10,817	$60,727.12	$124,201.70	$7.00
Commercial Land	145	7,958	$26,762.07	$3,135.66	$3.83
Industrial	55	14,838	$63,118.18	$65,773.75	$4.89
Total Comm/Industrial	495	10,426	$51,043.43	$82,245.91	$5.84
Exempt	438	104,174	$715,428.90	$1,050,893.52	$5.79
Exempt - 121A	37	6,545	$56,972.97	$349,229.73	$9.50
Total Exempt	475	96,537	$663,921.78	$996,006.50	$6.08
Apartments	141	13,079	$111,276.60	$524,920.86	$9.69
Condominium	79	9,598	$0.00	$0.00	$0.00
Single Family Housing	2,614	4,913	$46,746.90	$55,778.92	$10.75
Two Family Housing	2,648	5,014	$45,074.89	$74,613.82	$9.90
Three Family Housing	3,014	4,239	$42,019.48	$78,587.52	$11.01
Small Apartment House	99	5,757	$42,912.73	$141,469.27	$8.13
Residential Multi-Use	1,625	5,597	$49,141.41	$168,007.86	$9.52
Residential Land	2	5,325	$5,577.54	$148.49	$1.23
Total Residential	10,222	4,982	$39,029.69	$67,653.38	$8.96

Turning to the untiered parcels, we can immediately see that the average lot size, land value, and building value are much higher for the non-tiered parcels classified as apartments than for parcels of the same land use in Codman Square. While apartment property in Codman Square has an average lot size of 13,079 square feet (about a quarter of an acre), and an average land value of $111,276.60, an average building value of $564,920.86, and an average value of $9.69. The apartment property in our coverage of non-tiered sites has an average lot size of 118,355 square feet (close to four acres), an average land value of $586,000, and an average building value of $1,332,000. In addition the value of $4.95 per square foot calculated for the untiered sites, is almost half as large as the $9.69 per square foot value calculated for Codman Square. This analysis indicates there may be a large apartment complex on one of the 15 untiered parcels.

Table 9: Average Values by Land Use: Codman Square Untiered Parcels

Land use	Parcels	Average Lotsize (sqft)	Average Land Value	Average Building Value	Average Value ($/sqft)
Apartments	1	118,355	$586,000.00	$1,332,000.00	$4.95
Commercial	6	13,129	$60,750.00	$77,750.00	$5.42
Exempt	2	63,787	$320,000.00	$230,500.00	$5.43
Single Family Housing	2	4,841	$43,800.00	$79,000.00	$8.96
Two Family Housing	2	4,327	$42,950.00	$66,100.00	$10.45
Three Family Housing	2	3,433	$32,300.00	$90,050.00	$9.60

To determine how many of the untiered parcels are actually classified as apartment a count by land use of the 15 parcels was also done and appears in Table 9. This reveals that there is only 1 such parcel among the non-tiered sites. To determine whether the parcel is actually an outlier, it can excluded from our original analysis of average values for the non-tiered parcels. The parcel to exclude was determined by looking at the parcel and sites map in ArcView. Due to the large value of the parcel it would appear as a large parcel, and two large parcels that had a site on them were observed. The southern one is the YMCA which does not have a stateclass code which would classify it as an apartment property. Looking at the northern one we see it has a stateclass code of 113, which is in the apartment property category. According to the original 21E record the site is supposed to be the location of the Geneva Avenue Apartments.

The apartment complex was excluded and the original average lot size and property value query for the non-tiered 21E sites in Codman Square re-performed. The results observed by excluding the parcel fall back more in line with the values calculated for tiered 21E sites and for all the Codman Square parcels. This indicates that the property may be an outlier in the list of untiered sites in Codman Square as it has a large impact on statistics and is atypical of the other parcels in the data set. The average non-tiered 21E site in the CSNDC's service area has an average lotsize of 16,539 square feet which is above the average lot size for Codman Square and the tiered sites. The average land value and total average value for these sites is also higher than for Codman Square, with values of $88,757.14 and $188,600 respectively. However both the average building value and average per square foot land value are below the values calculated for Codman Square. These values are $99,842.86 and $7.24 per square foot respectively.

Table 10: Adjusted Average Values for Codman Square and 21E Parcels

Land use	Parcels	Average Lotsize (sqft)	Average Land Value	Average Building Value	Average Total Value	Average Value ($/sqft)
Codman Square + 1000m	11,482	8995	$65,335.81	$106,593.73	$171,929.55	$8.70
Tiered Sites	13	10273	$40,700.00	$46,161.54	$86,861.54	$6.06
Untiered Sites (with outlier)	15	23,327	$121,906.67	$181,986.67	$303,893.33	$7.09
Untiered Sites (w/out outlier)	14	16,539	$88,757.14	$99,842.86	$188,660.00	$7.24

These analyses have shown that in general we would expect a brownfield parcel in Codman Square to be larger than the average parcel in the service area of the CSNDC. The percentages of residential, commercial/industrial, and exempt parcels for Codman Square and the 21E sites, can partly explain the differences. Table 11 lists the amount and percent of parcels that are in these three uses for the 21E sites and Codman Square. The three classes are aggregations of the 13 land use types, Table 12 shows the values by the land uses in each grouping.

Table 11: Percent of Parcels by Land Use Type: All 21E Sites and Codman Square

Land use	Total 21E Parcels	Percent of 21E Parcels	Total Codman Square Parcels	Percent of Codman Square Parcels
Commercial/Industrial	14	50.00%	495	4.32%
Exempt	4	14.29%	475	4.14%
Residential Total	10	35.71%	10,495	91.54%

While commercial/industrial parcels make up only 4.32% of the parcels in Codman Square, they represent 50% of the 21E sites. Referring back to Table 8, the three classes that make up the commercial/industrial designation have higher average lotsizes than any of the uses that make up the residential designation in Codman Square. Given that 21E sites are more likely to be located on parcels with a commercial/industrial designation (Table 11) than residential ones that have smaller average lot sizes, the higher average lotsize for the 21E parcels is understandable.

Table 12: Parcel Count by Land Use and Parcel Type: Codman Square Area

Land use	Tiered Sites	Untiered Sites	All 21E Sites	Codman Square + 1000ft
Commercial	6	6	12	295
Commercial Land	1		1	145
Industrial	1		1	55
Total Comm/Industrial	8	6	14	495
Exempt	2	2	4	438
Exempt - 121A			0	37
Total Exempt	2	2	4	475
Apartments		1	1	141
Condominium			0	79
Single Family Housing	1	2	3	2614
Two Family Housing		2	2	2648
Three Family Housing	1	2	3	3014
Residential Multi-Use			0	99
Residential Land	1		1	1625
Small Apartment House			0	275
Total Residential	3	7	10	10495
Total Parcels	13	15	28	11465

The analysis of average values has also indicated that the average 21E parcel will have a lower average building value and average assessed value per square foot of land than the average parcel in Codman Square. If the site is tier classified, then it will have a lower average land value and total value than the average CSNDC parcel. However, the average land value and average total value are higher than for non-tier classified sites than for the average Codman Square parcel. The analysis has shown that the basic value and lotsize information can be used to better understand some basic characteristics of the 21E sites. The question now shifts to how the land use data contained in the assessor's data can analyzed to better understand the land use characteristics of these sites.

Analyzing the Land Use of Codman Square

The land use data that is contained within the assessor's data was analyzed using an analysis similar to the one we performed with the state land use coverage. However, before a buffer analysis was performed the land use data was drawn on a map of the parcels within 1,000 feet of the Codman Square Neighborhood Development Corporation so overall trends in the area could be observed. The site maps and the assessor's data were overlaid in AtcView to carry out this analysis. Figure 7 is a map of the residential uses in Codman Square, while Figure 8 presents the commercial and industrial uses.

Looking at the maps, it appears the Codman Square area is largely residential. These areas of one, two, or three family housing appear to be located on smaller side streets while apartment complexes and houses are located on more major roads. In, addition parcels of one, two, or three family housing appear to have a smaller lot size on average than the apartments, commercial, and industrial parcels. The commercial and industrial parcels also are located more on major roads. It appears as if residential uses form groupings that are bounded by apartment and commercial uses. Sites appear to be located either in or very close to commercial areas.

With a basic understanding of the land use in Codman Square, the results of the buffer analysis could be better understood. To perform the analysis, the tiered and untiered sites were buffered from their centroid by a 100 meter and a 250 meter buffer using the clip command in ArcInfo. The buffer distances were chosen for the same reasons outlined in the earlier analysis. These buffers were then intersected with the coverage of parcels in Codman Square using the intersect command in ArcInfo to obtain the parcels that lie at least in part within the buffered areas. Land use was analyzed using the 13 groupings recorded in the assessor's data, and was further grouped into commercial/industrial, exempt, and residential categories.

Figure 8: Residential Parcels within 1,000 Feet of the CSNDC Service Area

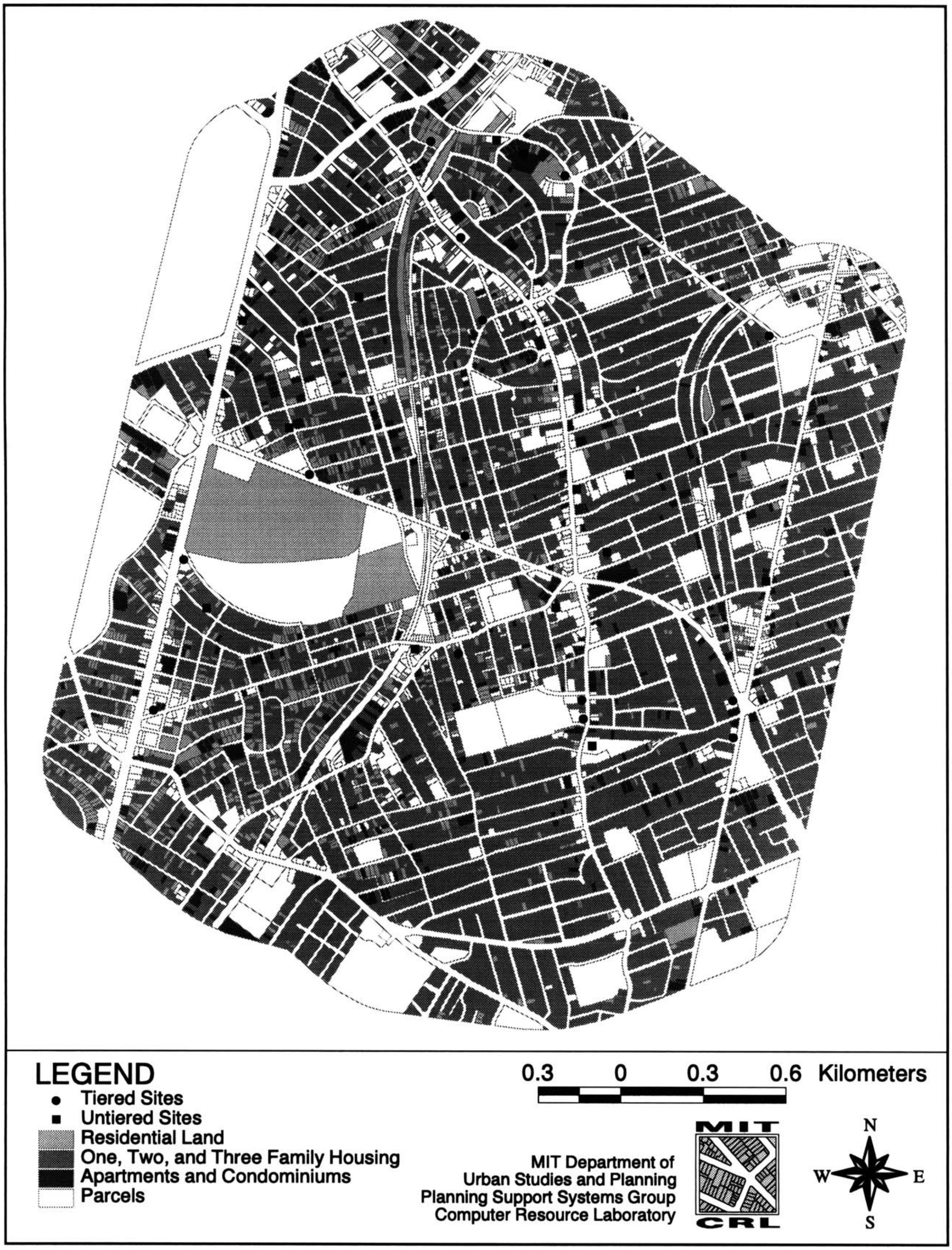
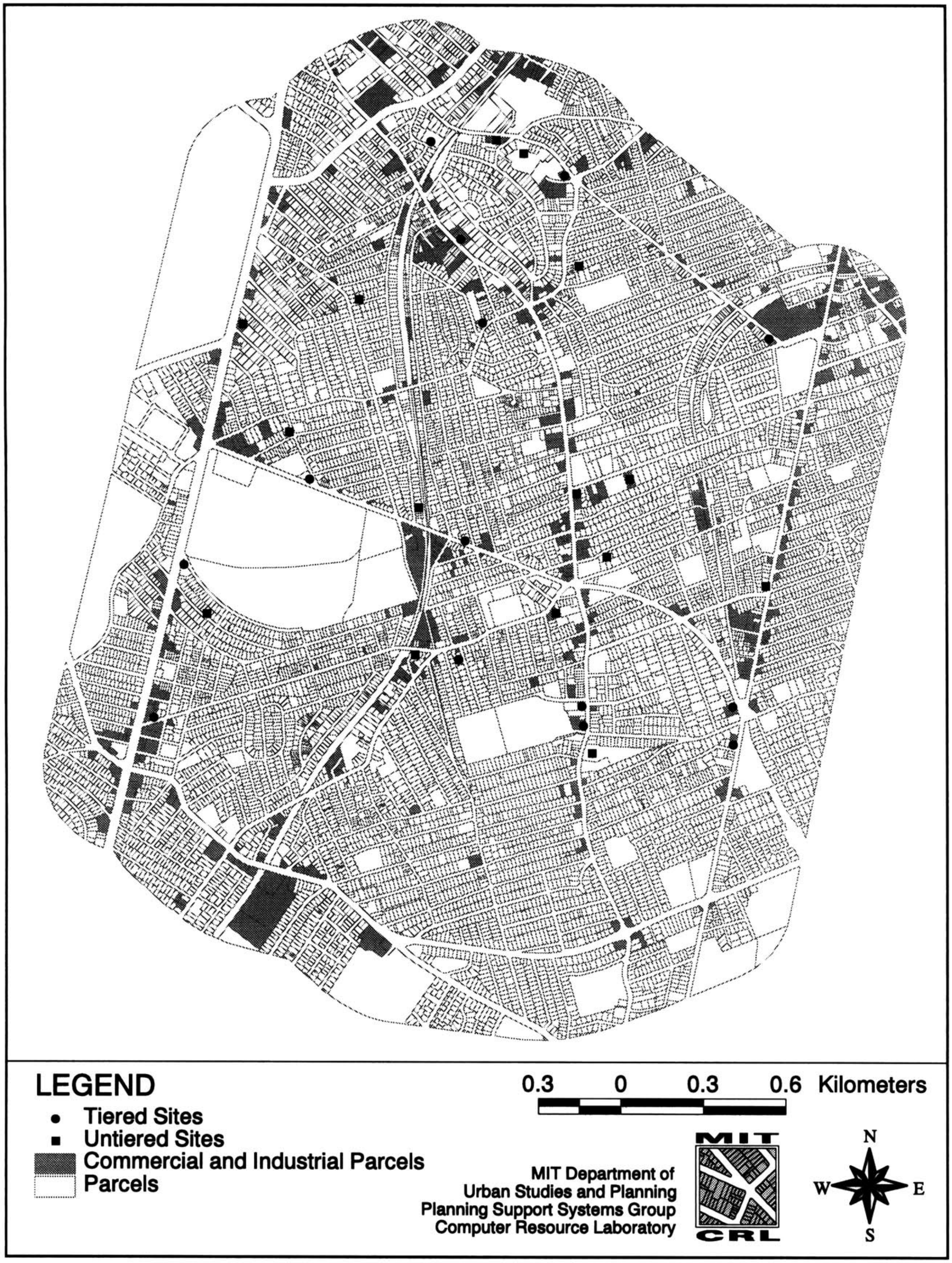


Figure 9: Commercial Parcels within 1,000 Feet of the CSNDC Service Area



In order to understand the local context of the sites, we first compared the percentage of parcels and area for each land use category between all the parcels in Boston and those parcels that fell at least partly in the 1,000 foot buffer of the CSNDC's service area. When the parcel coverage was clipped by any buffer only the areas of the parcels within the buffer were included in the resulting coverage. As a result the area of parcels can be computed in either of two ways. In the first method the lotsizes of all the parcels that fall at least partly within the buffer together can be added together. However as some large parcels may be located only partly in the buffer, this type of analysis can be misleading as area not within the buffer are included in analysis. The other method adds the areas of the parcels computed to lie within the buffer together to more accurately represent the land use within the buffered areas. For the analysis of area within buffered areas in this thesis, both methods were used when a buffered area was studied, including the 1,000 foot buffer of the CSNDC service area.

Table 13: Parcel Count and Lot Size by Land Use: Boston

Land use	Parcels	Percent of Total Parcels	Area (sqft)	Percent of Total Area
Commercial	4,879	3.54%	71,078,315	5.85%
Commercial Land	2,575	1.87%	28,481,210	2.34%
Industrial	1,427	1.03%	59,471,558	4.89%
Total Comm/Industrial	8,881	6.44%	159,031,083	13.09%
Exempt	5,788	4.19%	591,594,595	48.68%
Exempt - 121A	473	0.34%	10,994,448	0.90%
Total Exempt	6,261	4.54%	602,589,043	49.59%
Apartments	2,181	1.58%	29,900,346	2.46%
Condominium	39,836	28.87%	30,824,771	2.54%
Single Family Housing	29,444	21.34%	151,900,857	12.50%
Two Family Housing	18,513	13.42%	90,322,801	7.43%
Three Family Housing	15,988	11.59%	58,109,527	4.78%
Residential Multi-Use	2,406	1.74%	12,126,175	1.00%
Residential Land	11,365	8.24%	69,001,512	5.68%
Small Apartment House	3,126	2.27%	11,395,342	0.94%
Total Residential	122,859	89.03%	453,581,331	37.33%
Total Parcels	138,001	100.00%	1,215,201,457	100.00%

Table 13 lists the results of the analysis for Boston, while Table 14 presents the Codman Square results. Looking at parcel counts as a percentage of the total parcels in each coverage we find that there are slightly fewer parcels classified as exempt property type in Codman Square. 4.14% of the parcels are classified as exempt in Codman Square, while the percentage is 4.54% for the general City. The percentage of commercial/industrial parcels is less in Codman Square than in the City as 4.32% of its parcels are commercial/industrial compared to Boston's 6.44%. Residential uses accounted for 89.03% of the parcels in Boston while that percentage was only slightly higher at 91.52% for Codman Square. When we look at the actual land uses that are classified as residential, some more striking patterns emerge.

Table 14: Parcel Count and Lot Size by Land Use: Codman Square

	Parcels Within 1,000 Meters of the CSNDC Service Area		Lot Size of Parcels Within 1,000 meters of the CSNDC		Area Within the 1,000 Meter Buffer of the CSNDC Sevice Area	
Landuse	Number	Percent	Area	Percent	Area	Percent
Commercial	295	2.57%	3,191,045	3.09%	285,137	4.26%
Commercial Land	145	1.26%	1,153,895	1.12%	67,084	1.00%
Industrial	55	0.48%	816,101	0.79%	91,493	1.37%
Total Com/Industrial	495	4.32%	5,161,041	5.01%	443,714	6.62%
Exempt	438	3.82%	45,419,694	44.05%	1,402,987	20.94%
Exempt - 121A	37	0.32%	242,181	0.23%	21,823	0.33%
Total Exempt	475	4.14%	45,661,875	44.28%	1,424,810	21.27%
Apartments	141	1.23%	1,844,199	1.79%	143,291	2.14%
Condoninum	79	0.69%	758,238	0.74%	67,163	1.00%
Single Family Housing	2,614	22.80%	12,843,567	12.46%	1,156,656	17.26%
Two Family Housing	2,648	23.09%	13,276,611	12.88%	1,212,125	18.09%
Three Family Housing	3,014	26.28%	12,775,058	12.39%	1,171,858	17.49%
Residential Multi-Use	99	0.86%	554,091	0.54%	49,964	0.75%
Residential Land	1,625	14.17%	8,652,463	8.39%	887,478	13.25%
Small Apartment House	275	2.40%	1,583,247	1.54%	143,133	2.14%
Total Residential	10,495	91.52%	52,287,474	50.71%	4,831,667	72.11%
Total Parcels	11,467	99.98%	103,110,390	100.00%	6,700,191	100.00%

While condominium properties accounted for 28.87% of the parcels within Boston, that percentage drops almost nothing, or .69%, within Codman Square. However the percentage of two and three family housing sharply increases in Codman Square, which acts to offset the loss in residential parcels caused by the reduction of Condominium properties in the area. Two family housing comprised 13.42% of the parcels in Boston, while in Codman Square the percentage was more than doubled to 23.09%. Parcels classified as three family residential represented 11.59% of the parcels in the City, while they accounted for 26.28% of the parcels in Codman Square, which is more than double the percentage calculated for all of Boston.

The calculations of lotsize for parcels classified by each land use category as a percentage of total area for the Boston and Codman Square have similar patterns to the parcel counts. There are less exempt and commercial/industrial lands but more residential lands within Codman Square than in the rest of the city. The results indicate that Codman Square probably has a higher concentration of the triple decker walkups characteristic of the City's older neighborhoods, than in all of Boston.

Although exempt parcels accounted for about 4% of the parcels in Boston and Codman Square, they occupy far greater amounts of land. Since exempt property includes schools, places of worship, and parks it is not surprising that they occupy more area than their parcel count implies. Exempt property accounts for 49.59% of the City's lot area, while this percentage drops to 44.28% for Codman Square. The percentage of lot area occupied by commercial/industrial properties is also less for Codman Square than for all of Boston. Commercial/industrial parcels occupy 13.09% of the City's lot area but only 5.01% of the lot area in Codman Square.

However, residential parcels occupy 50.71% of the lot area in Codman Square while this percentage is lower at 37.33% for the City. The percentage of condominium properties behaves similarly to those calculated for the amount of parcels within each area. Condominium properties occupy significantly less lot area in Codman Square than in Boston, 0.74% opposed to 2.54%. The percentage of lotsize occupied by two and there family housing, 12.88% and 12.39%, however are much higher than the 7.43% and 4.78% calculated for the whole city. Residential uses make up 72.11% of the total lot area within Codman Square, which is also above the percentage of these parcels in Boston. Commercial uses made up 6.6% of the area within the Codman Square buffer while exempt properties made up 21.27% of the area within the same buffer.

These results indicate that Codman Square has a lower concentration of commercial/ industrial and exempt parcels than in the whole City. However, Codman Square has a higher concentration of residential parcels than the rest of the City, and these parcels also occupy more of the lot area for those parcels at least partly within the Codman Square buffer than in Boston. The percentages of lot area occupied by commercial/industrial and exempt properties are also less than those calculated for the whole City as well. The earlier analysis of average land value, indicated that the average commercial property in Codman Square had a lower land value and lot size than the City. With the results from this land use analysis, which indicates the service are of the CSNDC is more residential in character than the rest of the city, these results are not surprising. The Codman Square area is more residential in character and the commercial and industrial properties in the area are not as large as others in the City.

Analyzing the Land Use Around the Tiered Sites

With the land use characteristics of the Codman Square area better understood, we can more meaningfully analyze the land use characteristics within the buffered areas of the tiered and untiered sites. Table 15 lists the results of the land use analysis of parcels within the 100 meter buffer of tiered sites within the CSNDC's service area. The results indicate that the concentration of residential parcels in this area is slightly less than that for all of Codman Square. While residential parcels within the city constituted 91.52% of parcels in Codman square, this percentage is lower at 81.66% for the parcels within the 100 meter buffer. These parcels also make up more of the lotsize area of the parcels that are within the buffer area than they do in 1,000 meters of the CSNDC service area. Residential parcels make up 50.71% of the lotsize area within 1,000 feet of Codman Square, but make up 49.92% of the area within the 100 meter buffer. Residential parcels also make up 66.93% of the area within the 100 meter buffer which is slightly smaller than the 72.11% calculated for the area within a 1,000 meters of Codman Square.

Table 15: Parcel Count and Lot Size by Land Use: 100m Buffer of Tiered Sites in the CSNDC Service Area

	Parcels Within 100 Meters of Tiered Sites		Lot Size of Parcels Within 100 Meters of Tiered Sites		Area Within the 100 Meter Buffer of Tiered Sites		Percentages from the 1,000 Foot Buffer of the CSNDC Service Area		
Landuse	Number	Percent	Area	Percent	Area	Percent	Parcels	Lotsize	Area
Commercial	47	5.42%	653,229	7.22%	41,272	9.50%	2.57%	3.09%	4.26%
Commercial Land	20	2.31%	153,247	1.69%	9,064	2.09%	1.26%	1.12%	1.00%
Industrial	12	1.38%	156,108	1.73%	12,611	2.90%	0.48%	0.79%	1.37%
Total Comm/Industrial	79	9.11%	962,584	10.64%	62,947	14.48%	4.32%	5.01%	6.62%
Exempt	76	8.77%	3,548,374	39.22%	79,963	18.40%	3.82%	44.05%	20.94%
Exempt - 121A	4	0.46%	20,585	0.23%	809	0.19%	0.32%	0.23%	0.33%
Tottal Exempt	80	9.23%	3,568,959	39.44%	80,772	18.58%	4.14%	44.28%	21.27%
Apartments	19	2.19%	298,763	3.30%	14,817	3.41%	1.23%	1.79%	2.14%
Condoninum	4	0.46%	32,384	0.36%	2,988	0.69%	0.69%	0.74%	1.00%
Single Family Housing	140	16.15%	705,594	7.80%	53,161	12.23%	22.80%	12.46%	17.26%
Two Family Housing	128	14.76%	697,479	7.71%	48,870	11.24%	23.09%	12.88%	18.09%
Three Family Housing	229	26.41%	931,766	10.30%	66,636	15.33%	26.28%	12.39%	17.49%
Residential Multi-Use	16	1.85%	98,186	1.09%	7,604	1.75%	0.86%	0.54%	0.75%
Residential Land	150	17.30%	1,992,118	22.02%	89,887	20.68%	14.17%	8.39%	13.25%
Small Apartment House	22	2.54%	91,784	1.01%	6,936	1.60%	2.40%	1.54%	2.14%
Total Residential	708	81.66%	4,516,927	49.92%	290,898	66.93%	91.52%	50.71%	72.11%
Total Parcels	867	100.00%	9,048,470	100.00%	434,618	100.00%	99.98%	100.00%	100.00%

When we look at the residential uses in detail, almost all occupy less of the lot area of the parcels at least partly within the 100 meter buffer than in Codman Square. However there is a dramatic increase in the percentage of lot area occupied by residential land within the buffer zone from the percentage calculated for Codman Square. Residential land indicates parcels that are zoned for residential use but are not developed or are vacant. While parcels of this type occupied 8.39% of the lot area in Codman Square they occupy 22.02% of the lot area of the parcels at least partly within the buffer. Within the 1,000 meter buffer of Codman Square residential land made up 13.25% of the area while slightly more 20.68% of the area within the buffer of the tiered sites was residential land. This indicates that many of the larger parcels of residential land, are located within the 100 meter buffer of the tiered sites in Codman Square.

While the concentration of residential parcels within the buffer was less than that calculated for Codman Square, the concentrations of exempt and commercial/industrial parcels are higher. Commercial parcels accounted for 4.32% of the parcels in Codman Square, while they represent 9.11% of the parcels within the buffer. Similarly, 4.14% of the parcels in Codman square were exempt while this percentage rises to 9.23% within the buffer. However the percentage of the lot area exempt parcels occupy within for those parcels at least partly within the buffer is 35.57% while similar parcels occupy 44.28% of the lot area in Codman Square. The parcels also occupy slightly less of the area within the 100 meter buffer than with the 1,000 meter buffer of the CSNDC. These percentages are 19.20% and 21.27% respectively. This indicates that the increase in land area percentage of residential parcels may have come at the cost of exempt properties.

Table 16: Average Land Values for Parcels within 100 Meters of Tiered Sites

Landuse	Parcels	Average Lotsize (sqft)	Average Land Value	Average Building Value	Average Land Value ($/sqft)
Commercial	47	13,516	$67,414.89	$158,000.00	$6.25
Commercial Land	20	7,662	$20,875.00	$1,725.00	$3.25
Industrial	12	13,009	$56,916.67	$68,966.17	$4.78
Total Comm/Industrial	79	11,957	$54,037.97	$104,912.58	$5.27
Exempt	76	46,689	$188,782.90	$398,701.32	$5.47
Exempt - 121A	4	5,146	$54,375.00	$269,625.00	$10.35
Total Exempt	80	44,612	$182,062.50	$392,247.50	$5.72
Apartments	19	15,724	$118,131.58	$530,657.90	$9.85
Condoninum	4	8,096	$0.00	$0.00	$0.00
Single Family Housing	140	5,040	$42,620.71	$49,695.71	$9.51
Two Family Housing	127	5,447	$42,288.98	$70,087.40	$9.13
Three Family Housing	223	4,069	$39,234.93	$81,065.07	$11.11
Small Apartment House	22	4,172	$34,545.45	$119,181.82	$8.54
Residential Multi-Use	16	6,137	$68,781.25	$275,906.25	$10.04
Residential Land	151	19,725	$6,230.46	$179.47	$1.09
Total Residential	702	8,233	$35,830.79	$72,836.86	$8.10

Table 16 presents the results of the average assessed land value calculations for the parcels within the 100 meter of the tiered sites. Overall, the commercial parcels in the buffer have a higher average lot size, land value, and building value than commercial parcels in all of Codman Square (see Table 8 for reference). However, the average per square foot land value is about 50 cents lower for these parcels. The average land value per square foot is also about 50 cents lower for the residential parcels, which have a higher average lotsize and building value than residential parcels in all of Codman Square. Exempt properties in the buffer have lower values for all values. The values calculated for each land use are fairly constant in the analysis of the other biffers. Therefore only the summary statistics for the three main groupings of land use; commercial/industrial, exempt, and residential; will be presented in futures table for these calculations within the other buffers.

These results indicate that the concentration of residential parcels close to tiered sites in Codman Square is lower than that for the whole area, but these parcels have a slightly larger average lot size and occupy slightly more of the area within the buffer than those parcels in Codman Square. The areas in close proximity to these sites are more commercial and industrial in their makeup than the rest of Codman Square. In addition although some of the averages were in some cases higher than those for Codman Square, the average per square land values were lower for all the parcels. This may indicate that the sites may be located in slightly more economically depressed areas. With these results the question turns to what happens to these percentages as the buffer distance around the sites is increased. Table 17 presents the results of the land use analysis of the parcels within a 250 meter radius of the tiered sites within Codman Square.

The percentage of residential parcels increased from 81.68% within the 100 meter buffer, to 87.38% within the larger buffer area. This value is closer to the 91.52% for the parcels within the 1,000 meter buffer of the CSNDC's service area, though still lower. These parcels now comprise 60.54% of the lot area of the parcels at least partly within the buffer, up from 54.84% in the smaller buffer. This value is above that calculated for the parcels at least partly within the buffer of the CSNDC. Looking at how commercial properties are arranged along majors and define residential parcels, our buffer is probably only enclosing the center of these residential properties.

Table 17: Parcel Count and Lot Size by Land Use: 250m Buffer of Tiered Sites in the CSNDC Service Area

	Parcels Within 250 Meters of Tiered Sites		Lot Size of Parcels Within 250 Meters of Tiered Sites		Area Within the 250 Meter Buffer of Tiered Sites		Percentages from the 1,000 Foot Buffer of the CSNDC Service Area		
Landuse	Number	Percent	Area	Percent	Area	Percent	Parcels	Lotsize	Area
Commercial	127	3.36%	1,538,372	5.39%	126,246	6.20%	2.57%	3.09%	4.26%
Commercial Land	78	2.06%	442,806	1.55%	37,973	1.86%	1.26%	1.12%	1.00%
Industrial	27	0.71%	393,394	1.38%	37,059	1.82%	0.48%	0.79%	1.37%
Total Comm/Industrial	232	6.14%	2,374,572	8.31%	201,278	9.88%	4.32%	5.01%	6.62%
Exempt	221	5.85%	8,781,095	30.74%	361,979	17.77%	3.82%	44.05%	20.94%
Exempt - 121A	24	0.63%	116,100	0.41%	9,918	0.49%	0.32%	0.23%	0.33%
Total Exempt	245	6.48%	8,897,195	31.14%	371,896	18.26%	4.14%	44.28%	21.27%
Apartments	50	1.32%	594,718	2.08%	47,871	2.35%	1.23%	1.79%	2.14%
Condoninum	32	0.85%	228,954	0.80%	20,097	0.99%	0.69%	0.74%	1.00%
Single Family Housing	763	20.19%	3,794,846	13.28%	304,920	14.97%	22.80%	12.46%	17.26%
Two Family Housing	672	17.78%	3,468,951	12.14%	290,860	14.28%	23.09%	12.88%	18.09%
Three Family Housing	987	26.11%	4,005,798	14.02%	339,025	16.65%	26.28%	12.39%	17.49%
Residential Multi-Use	46	1.22%	275,391	0.96%	24,419	1.20%	0.86%	0.54%	0.75%
Residential Land	656	17.35%	4,448,223	15.57%	394,680	19.38%	14.17%	8.39%	13.25%
Small Apartment House	97	2.57%	478,697	1.68%	41,663	2.05%	2.40%	1.54%	2.14%
Total Residential	3,303	87.38%	17,295,578	60.54%	1,463,536	71.86%	91.52%	50.71%	72.11%
Total Parcels	3,780	100.00%	28,567,345	100.00%	2,036,710	100.00%	99.98%	100.00%	100.00%

The percentages calculated for commercial/industrial properties within the larger buffer of tiered sites in Codman Square have both fallen from their values in the 100 meter buffer and more closely approach the values calculated for the whole area. These parcels now account for 6.14% of the parcels within the buffer down from 9.10%. They represent 8.31% of the lot area of the parcels at least partly within the 250 meter buffer, while these properties made up 10.64% of the lot area of the parcels at least partly within the 100 meter buffer. The percentage of the buffer area occupied by commercial industrial properties also has fallen from 14.48% to 9.88% as the buffer distance increased.

Exempt properties make up 6.48% of the parcels within the larger buffer area, down from the 9.22% calculated for the parcels within the 100 meter buffer, to more closely resemble the 4.14% calculated for the parcels within the 1,000 foot buffer of Codman Square. However, while we would expect the percent of lot area of the parcels at least partly within the buffer to increase from the 39.44% calculated for the 100 meter buffer so it would get closer to the 44.28% calculated for the parcels at least partly within the 1,000 foot buffer of the Codman Square, the value drops. Exempt parcels occupy only 30.11% of the lot area of the parcels within the 250 meter buffer of tiered sites within Codman Square. The percentage of area in the buffer occupied by the exempt properties also fell very slightly from 18.58% within the 100 meter buffer to 18.26% within the 250 meter buffer. These figures could also indicate an outlier effect in the smaller amount of records included within the buffer area. This would be caused if there was a large exempt property in Codman Square that is not included in the buffered area. This would decrease the percentage of land exempt parcels occupy in the buffer while increasing the values for other uses, in this case residential parcels. However it should be noted that the percent of parcels classified as exempt fell as we increased our buffer distance.

Table 18: Average Land Values for Parcels Within 250 Meters of Tiered Sites

Land use	Parcels	Average Lotsize (sqft)	Average Land Value	Average Building Value	Average Land Value ($/sqft)
Total Comm/Industrial	232	10,235	$48,122.84	$77,464.34	$5.37
Total Exempt	245	36,464	$184,090.16	$765,346.75	$5.85
Total Residential	3,303	5,533	$34,812.20	$65,693.70	$8.15

Table 18 presents the results of the analysis of land value for the parcels within 250 meters of the sites. Like the previous analysis for the parcels within the 100 meter buffer, the average per square foot land value for all types of land use are all slightly lower than those calculated for Codman Square (see Table 8), but are all slightly higher than those calculated within the 100 meter buffer. However if we look back at Table 16, we notice that the average lotsize for all the parcels has decreased. Residential and commercial/industrial parcels also saw a decrease in their average building and land values, while these average rose for exempt parcels. This indicates that the sites are located in areas that are made up of slightly smaller parcels than Codman Square as a whole and lie in slightly less valuable areas of land. However, as we move farther away from the sites we begin to obtain average values that are closer to those calculated for the whole area.

The analysis has shown that the areas surrounding brownfield sites in Codman square are more commercial and industrial in nature than would be expected for the neighborhood. They also contain a higher percentage of exempt parcels. Consequently there is a drop in the amount of residential parcels in this area. However, commercial and industrial parcels occupy more lot area and buffer area than expected while exempt parcels occupy less. This indicates that the concentration of commercial industrial parcels is higher around the parcels though still small compared with the concentration of residential parcels. The residential percentages are similar across the buffers as well with the exception of residential land parcels which had higher percentages than expected in the smaller buffer area. This indicates the sites are close to residential parcels but no closer than most commercial and industrial properties.

Analyzing the Land Use Around the Untiered Sites

After performing the analysis on the tiered sites within Codman Square, the question turns to whether or not the areas around the untiered sites are similar. Once again the sites were buffered by 100 and 250 meters and intersected with the assessor's data. Table 19 represents the results from the analysis of the 100 meter buffer while Table 21 presents the results of the analysis with the 250 meter buffer.

The parcel counts indicate that concentrations of commercial/industrial properties and exempt properties are higher within the buffer than those in Codman Square. While commercial/ industrial parcels represent 4.32% of the parcels in Codman Square they represent 6.50% of the parcels within the buffer area. Exempt properties make up 6.08% of the parcels within the buffered area, but only 4.14% in Codman Square. While the concentration of these parcels are higher within the buffer area, the concentration of residential parcels is slightly lower. These parcels represent 91.52% of the parcels within Codman Square and 87.43% of the parcels within the buffered area. These results indicate that again the areas around the sites have higher concentrations of commercial/industrial and exempt properties than within Codman Square. However the percentages calculated within the 100 meter buffer of the untiered sites are closer to those calculated for all of Codman Square, than those calculated within the buffer of the tiered sites were.

Table 19: Parcel Count and Lot Size by Land Use: 100m Buffer of Untiered Sites in the CSNDC Service Area

	Parcels Within 100 Meters of Untiered Sites		Lot Size of Parcels Within 100 Meters of Untiered Sites		Area Within the 100 Meter Buffer of Untiered Sites		Percentages from the 1,000 Foot Buffer of the CSNDC Service Area		
Landuse	Number	Percent	Area	Percent	Area	Percent	Parcels	Lotsize	Area
Commercial	53	4.47%	575,754	1.80%	37,199	6.66%	2.57%	3.09%	4.26%
Commercial Land	15	1.27%	61,503	0.19%	5,481	0.98%	1.26%	1.12%	1.00%
Industrial	9	0.76%	216,958	0.68%	5,493	0.98%	0.48%	0.79%	1.37%
Total Comm/Industrial	77	6.50%	854,215	2.67%	48,174	8.63%	4.32%	5.01%	6.62%
Exempt	70	5.91%	25,713,042	80.25%	103,093	18.46%	3.82%	44.05%	20.94%
Exempt - 121A	2	0.17%	15,379	0.05%	1,008	0.18%	0.32%	0.23%	0.33%
Total Exempt	72	6.08%	25,728,421	80.30%	104,101	18.64%	4.14%	44.28%	21.27%
Apartments	18	1.52%	332,439	1.04%	25,637	4.59%	1.23%	1.79%	2.14%
Condoninum	7	0.59%	53,404	0.17%	3,135	0.56%	0.69%	0.74%	1.00%
Single Family Housing	269	22.70%	1,438,674	4.49%	107,309	19.22%	22.80%	12.46%	17.26%
Two Family Housing	260	21.94%	1,335,842	4.17%	95,750	17.15%	23.09%	12.88%	18.09%
Three Family Housing	293	24.73%	1,250,013	3.90%	98,809	17.70%	26.28%	12.39%	17.49%
Residential Multi-Use	16	1.35%	85,232	0.27%	7,714	1.38%	0.86%	0.54%	0.75%
Residential Land	150	12.66%	814,384	2.54%	57,869	10.36%	14.17%	8.39%	13.25%
Small Apartment House	23	1.94%	148,170	0.46%	9,844	1.76%	2.40%	1.54%	2.14%
Total Residential	1,036	87.43%	5,458,158	17.04%	406,068	72.73%	91.52%	50.71%	72.11%
Total Parcels	1,185	100.00%	32,040,794	100.00%	558,342	100.00%	99.98%	100.00%	100.00 %

The question then shifts to how much area the land uses occupy within the buffer. A quick look at Table 19 immediately shows an intriguing result. Although exempt parcels represented 6.08% of the parcels at least partly within the buffered area, they make up over 80% of the total lot area of all parcels that lie at least partly in the buffer. However the exempt parcels occupy 18.64% of the area that falls within the buffer. That is slightly below the 21.27% calculated for the area within the 1,000 foot buffer of the CSNDC's service area. Rather it indicates the sensitivity of the area calculation to the computation method. In one case, only the area within the buffer was considered.

In the other the lotsizes of all the parcels at least partly within the buffer were considered, so areas outside the buffer were included.

When we look at the other values for the percentage of area within the buffer we see that residential uses make up almost the same percentage of area in the buffer as they do within the area of the 1,000 foot buffer of the CSNDC service area. these values are 72.73% and 72.11%. Commercial/industrial uses occupy slightly more of the area within the buffer than they do within 1,000 meters of Codman Square, which can help to explain the decrease in the percentage of area occupied by exempt properties. Commercial and industrial uses make up 8.63% of the area within the buffer while they make up 6.62% of the area within 1,000 feet of the CSNDC. The differences in area percentages for the same set of parcels is not a data error.

Table 20: Average Land Values for Parcels Within 100 Meters of Untiered Sites

Landuse	Parcels	Average Lotsize (sqft)	Average Land Value	Average Building Value	Average Land Value ($/sqft)
Total Comm/Industrial	228	8,842	$40,734.65	$67,974.68	$5.59
Total Exempt	209	139,548	$924,817.31	$811,335.33	$5.72
Total Residential	4,046	5,788	$37,045.72	$65,800.00	$8.65

Table 20 presents the results of the land value analysis for parcels within 100 meters of the untiered sites. Like the analysis for the buffers of the tiered sites the average per square foot land value is lower than the Codman Square values for all types of land use. However the values are all about 35 cents higher than the values in the 100 meter buffer of tiered sites, for al land use types. The average land value and building value are higher for both residential and commercial properties than the averages computed for all of Codman Square and the 100 meter buffer of tiered sites. While the average lotsize of commercial and industrial properties are higher than the values calculated for Codman Square, it is still below that calculated for the 100 meter buffer of the tiered sites. The average lotsize of residential parcels is higher than the value computed for all of Codman Square, but smaller than that calculated for the 100 meter buffer of the tiered sites. A striking finding is that the average lotsize, land value, and building value are all higher for parcels in this buffer.

Some very large parcels of exempt property must therefore lie near the boundaries of the buffer area or there is some property creating an outlier effect (see Figure 7). Because of the overwhelming percentage of exempt property, the percentage of lot area of the parcels ar least partly within the 100 meter buffer occupied by commercial/industrial and residential properties are substantially below the values calculated for Codman Square. However the percentage of residential parcels within the buffer is above that calculated for Codman Square, while the residential percentage is lower than that for Codman Square, which indicates that there are more commercial and industrial parcels within the 100 meter buffer area.

Table 21: Parcel Count and Lot Size by Land Use: 250m Buffer of Non-Tiered Sites in the CSNDC Service Area

	Parcels Within 250 Meters of Untiered Sites		Lot Size of Parcels Within 250 Meters of Untiered Sites		Area Within the 250 Meter Buffer of Untiered Sites		Percentages from the 1,000 Foot Buffer of the CSNDC Service Area		
Landuse	Number	Percent	Area	Percent	Area	Percent	Parcels	Lotsize	Area
Commercial	125	2.79%	1,138,484	2.09%	92,729	3.96%	2.57%	3.09%	4.26%
Commercial Land	74	1.65%	388,427	0.71%	30,911	1.32%	1.26%	1.12%	1.00%
Industrial	29	0.65%	488,985	0.90%	32,442	1.38%	0.48%	0.79%	1.37%
Total Comm/Industrial	228	5.08%	2,015,896	3.70%	156,082	6.66%	4.32%	5.01%	6.62%
Exempt	192	4.28%	28,914,440	53.09%	440,777	18.80%	3.82%	44.05%	20.94%
Exempt - 121A	17	0.38%	111,553	0.20%	9,226	0.39%	0.32%	0.23%	0.33%
Total Exempt	209	4.66%	29,025,993	53.30%	450,003	19.20%	4.14%	44.28%	21.27%
Apartments	56	1.25%	675,596	1.24%	57,787	2.46%	1.23%	1.79%	2.14%
Condoninum	34	0.76%	262,115	0.48%	21,892	0.93%	0.69%	0.74%	1.00%
Single Family Housing	872	19.44%	4,408,325	8.09%	375,413	16.01%	22.80%	12.46%	17.26%
Two Family Housing	997	22.22%	4,923,244	9.04%	428,352	18.27%	23.09%	12.88%	18.09%
Three Family Housing	1,263	28.15%	5,452,208	10.01%	457,267	19.50%	26.28%	12.39%	17.49%
Residential Multi-Use	43	0.96%	204,708	0.38%	18,328	0.78%	0.86%	0.54%	0.75%
Residential Land	672	14.98%	6,854,841	12.59%	325,964	13.90%	14.17%	8.39%	13.25%
Small Apartment House	109	2.43%	635,971	1.17%	53,273	2.27%	2.40%	1.54%	2.14%
Total Residential	4,046	90.19%	23,417,008	43.00%	1,738,277	74.15%	91.52%	50.71%	72.11%
Total Parcels	4,486	99.93%	54,459,897	100.00%	2,344,363	100.00%	99.98%	100.00%	100.00%

As the buffer around the non-tiered sites increases to 250 meters the calculated percentages more closely resemble those from the analysis of all parcels in Codman Square (See Table 21). The percentages of exempt or commercial/industrial parcels have both fallen while the percentage of residential parcels has risen, from the values calculated within the 100 meter buffer of the untiered sites. Residential parcels accounted for 87.43% of the parcels within the 100 meter buffer, but account for 90.19% of the parcels within the larger buffer of the untiered sites. This number is very close to the 91.52% calculated for Codman Square. Commercial/industrial represent 5.08% of the parcels within the buffer area, which is lower than the 6.50% calculated within the smaller buffer, but still slightly larger than the 4.14% calculated for Codman Square. The percentage of exempt parcels within the 250 meter buffer is 4.66% whereas the percentage was only 6.08% in the 100 meter buffer. This percentage is still above the 4.14% calculated for Codman Square.

The percentages of lot area calculated for each type of land use also move towards the values calculated for all of Codman Square as the buffer distance increases around the sites. Commercial and industrial parcels represent 3.70% of the lot area of the parcels that lie at least partly within the buffer which is higher than the 2.70% calculated within the 100 meter buffer, and is loser to the 5.01% calculated for all of Codman Square. The percentage of residential lot area for the parcels that lie at least partly within the buffer has dramatically increased from 17.04% in the smaller buffer to 43.00% in the larger buffer, which is still below the 50.71% calculated for Codman Square. Exempt parcels make up 53.30% of the lot area of the parcels at least partly within the larger buffer which is down from the 80.30% calculated in the smaller buffer. This indicates the outlier effects on area calculations that may be caused by some exempt properties is decreasing as the distance from the sites increases.

When we look at the actual percentage of area occupied by each type of land use within the larger buffer of the tiered sites we notice that they are extremely close to the values calculated for the Codman Square area. Commercial properties occupy 6.66% of the area within the 250 meter buffer, while these parcels make up 6.62% of the area within 1,000 feet of the CSNDC. Exempt properties account for 21.27% of the area within Codman Square, and slightly less or 19.20% of the area within the 250 meter buffer. Residential properties are in a slightly higher concentration within the larger buffer and represent 74.15% of the area within the 250 meter buffer of the untiered sites and 72.11% for the area within Codman Square.

Table 22: Average Values for Parcels Within 250 Meters of Untiered Sites

Land use	Parcels	Average Lotsize (sqft)	Average Land Value	Average Building Value	Average Land Value ($/sqft)
Total Comm/Industrial	228	8,842	$40,734.65	$67,974.68	$5.59
Total Exempt	209	139,548	$924,817.31	$811,335.33	$5.72
Total Residential	4,046	5,788	$37,045.72	$65,800.00	$8.65

Table 22 presents the results of the average value analysis of parcels within the 250 meter buffer of untiered sites. The average values for commercial properties are all below the values computed for the parcels within Codman Square and the 100 meter buffer of untiered sites. The pattern appears for exempt properties which all had all the average values fall beneath the values computed for Codman Square as a whole. However, both the average per square foot land value and lotsize rose from the values computed in the smaller buffer of the untiered sites. The average lotsize, building value, and land value for residential properties are all larger than those calculated for all of Codman Square, while the per square foot land value is less. This indicates that the areas around untiered sites in general contain larger residential properties. The amount of these properties appears to increase as we move farther away from the properties as well. However, the lower average per square foot values for all types of parcels indicates that the areas around the sites are slightly less valuable than areas farther away from the properties. However, these differences are fairly slight indicating that differences in land use are more significant for the brownfield sites in Codman Square.

The analysis of both buffers has indicated that the areas close by contaminated properties in Codman Square tends to contain higher concentrations of exempt and commercial/industrial parcels than the rest of the area while concentration of residential parcels is slightly less nearby these sites.

However, these differences are less noticeable near untiered sites which have higher concentrations of residential properties nearby. Since untiered sites were reported to Mass DEP after the revisions to the MCP took effect in 1993, they tend to be sites that have been reported with lower levels of contamination that can be more easily cleaned up by LSP's and private initiative this is not surprising. In addition to higher concentrations of commercial/ industrial parcels within all the buffers, the areas occupied by these parcels are higher than would be predicted from the percentages calculated for the Codman Square area, except for within the 100 meter buffer of untiered sites. The analysis has also shown that as the buffer distance around the sites increases the more the land use characteristics of the area resemble those of the Codman Square area.

The results from all the buffers indicates that brownfield sites in Boston and Codman Square lie within areas of higher concentrations of commercial and industrial lands though these concentrations are still small compared to residential properties. However as the analysis using assessor's data for Codman Square showed, the percentages for most residential uses are similar across all the buffers, with the big difference being residential lands. This indicates that the sites are close to residential properties, but no more closer than most commercial and industrial properties.

The results of analysis might be construed as saying all brownfield properties should be redeveloped for commercial and industrial use. As newer brownfield programs are developing end-use cleanup standards for these types of developments it can lower clean costs on the sites, since they would not have to be cleaned to pristine standards, and facilitate their reuse. However, the presence of residential use around the properties should indicate that a more careful, thought out, comprehensive approach to the site redevelopment should be taken. This approach would use the actual surroundings of an individual site to determine its redevelopment strategy.

Our analysis has shown the usefulness of using existing state and local data in a GIS for land use analysis of brownfield sites. However the data from each source is suited to a specific level of detail. The state land use coverage, *bost-lu*, groups land use into broadly defined areas (See Figure 8). While the data identifies key areas of certain uses such as commercial strips, it does not differeniate between the uses on individual sites within these areas. State data in most cases can therefore be used to document the land use immediately adjacent to brownfield sites in detail. However it can be used to paint the larger picture of the land use context of brownfield in the larger city or community.

Local data, where available, provides a way to enrich and deepen analysis that just uses state data. The parcel coverage of Boston allowed fluctuations within the broader areas defined in the state land use coverage to be observed because of its parcel level of aggregation (see Figure 8). In addition the level of detail of the data can enable the land use immediately adjacent to sites to be documented. To a neighborhood or local agency concerned with brownfields such as the CSNDC such detail is needed. In many cases a site may be located on a commercial strip in a largely residential area. A state coverage would most likely classify such a commercial strip as residential. It can identify micro trends in land use, which can help a community better identify potential future uses on the site most in keeping with surrounding land use patterns. Returning to the example of a commercial strip, if the commercial properties nearby were not identified commercial reuse strategies in general might not be considered redevelopment options when in fact such uses would complement surrounding uses. While this analysis can inform a community of potential reuse strategies for brownfields, it can not take the place of the planning process for each site which can determine the ultimate use on a site. However, the results of the analysis are a tool that can help a community identify broader steps it can take to provide for greater reuse opportunities on the sites to facilitate site redevelopment.

VII: Conclusions and Recommendations

One of the greatest concerns in many communities is that they do not know the extent of their brownfields situation. While programs such at the EPA's Brownfields Pilot program provide funds to selected communities to inventory and perform preliminary assessment of their contaminated or potentially contaminated properties, not every community has the resources to perform the comprehensive field survey entailed in this approach. Those communities to which these funds are unavailable are often left with a brownfields situation they can not adequately understand.

This thesis has looked at the ways geographic information systems and other information technologies can be used with existing data sources in efforts to better inform brownfield decision making. The growth of brownfield redevelopment programs at all levels of government have abandoned the historic narrow environmentally focused approach towards the redevelopment of sites. These new approaches also look at the economic and social surroundings of these properties to help guide redevelopment decisions and provide certain forms of relief. These programs have become in many cases interdisciplinary programs between various types of agencies.

At the same time these programs are evolving, the use of GIS in the planning process is becoming more established. GIS can allow different geographic data sets pertaining to different issues to be combined. It can therefore not only act as a means to improve the quality of spatial analysis, but can be used to compile different data together to facilitate that analysis. As such the question turns to how the existing framework of GIS can be tapped by brownfield redevelopment efforts,

Programs set up to facilitate brownfield redevelopment must first determine what aspect of the sites is to be studied. The data that can be used can either be built up for individual projects or be obtained from existing sources. The former approach involves field surveys of conditions and can be quite costly. However, existing state and local data can be used to perform meaningful spatial analysis and avoids the costs associated with developing data in the former approach. If these standard data sets can be overlaid correctly, many meaningful spatial analysis can be performed. Sites located in areas meeting certain economic criteria can be identified as they may be able to obtain state assistance in redevelopment. Neighbors threatened by a spill on a particular property can be notified and included in developing reuse strategies. Land use around the sites can be analyzed to help propose redevelopment strategies that take surrounding uses into consideration.

This thesis looked at how such a land use analysis could be performed for the City of Boston using existing data rather than building up individual data sets. The state GIS program, MassGIS provided a land use coverage while the Massachusetts Department of Environmental Protection provided a list of sites were combined to perform a variety of spatial and buffer analyzes. However this analysis was limited by the detail provided by state information. Local assessor's data was then added to the GIS. As the data set was large, the analysis then focused on the service area of the Codman Square Neighborhood Development Corporation to look at how local data can be used in the analysis.

Despite the difficulties in getting data to match up in this case, once they were lined up meaningful spatial analysis could occur. Existing state land use data in the MassGIS bost-lu coverage and in assessor's data for the City of Boston and Codman Square has indicated that the brownfields in these areas are located in areas with higher than average percentages of non-residential uses. As Massachusetts revises its brownfield strategy such developments may be able to be cleaned to less stringent standards. Instead of reducing chemical contamination to pristine, non-existent levels, they can be cleaned to levels that pose no significant risk to humans. Massachusetts is also proposing more liability relief for innocent third parties which undertake site cleanups on their own. The two proposed programs are trying to reduce the uncertainties about liability and clean up costs of these parcels, to developers, to make the properties more attractive for redevelopment.

The analysis in this thesis shows that it is possible to use existing data sources to better understand the extent of a community's brownfields situation. While the use of state and local data in a brownfields GIS does not allow a community to assess their properties in depth, to determine past owners or obtain a preliminary assessment of the actual contamination on a site, as EPA

Brownfield Pilot Project communities are able to do, it does allow a community to determine the location and characteristics of past and present contaminated properties. By using available, primarily local, data to analyze the characteristics of brownfield sites, other sites that have similar characteristics may be identified and investigated as potential contaminated properties. In addition once the spatial distribution of brownfield sites is known it may be possible to combine sites in to create a comprehensive geographic approach to redeveloping these sites.

Accommodating GIS into the Brownfield Programs

GIS can help a community gather together the many existing data sets to be able to better utilize these programs. Economic data can be used to determine sites that lie in areas of lower land value, that may qualify for these funds. State may also provide maps of certain economic target areas that can used to determine whether a site lies in such an area and can receive other funds provided by the state. Social data, such as information on crime rates, can be used to search through a list of sites and determine which ones have lower crimes rates. These sites may be seen as more attractive areas to develop if some liability relief can be provided. The economic data can also be used to find brownfield sites near areas with a large amount of nearby workers. These sites may also be attractive to developers since reuse commercial and industrial reuse strategies on such sites may be able to use the surrounding workforce in the redeveloped parcels. In addition communities may want to identify these sites so they can focus development efforts at these sites to improve the workforce as well.

GIS can then be a tool to help a community better understand its brownfields. Properties that may be able to obtain liability relief, economic assistance or in general are more attractive to developers be identified. Reuse strategies can also be proposed to take advantage of programs geared for certain types of use. GIS and the toolbox of programs are both tools that can be used to aid brownfield redevelopment. They can not be used to propose the same reuse strategies for all the sites within a municipality. However they can be used to identify general trends in brownfields and help a community become more aware of the various ways the sites can be propelled into active use again.

The exact strategy for each site still needs to be determined and planned individually. However, the use of GIS can help a community develop a more complete set of options for site redevelopment.

Utilizing Existing Data in Brownfield Redevelopment

Many communities that face brownfield problems believe they need to develop their own sets of data relating to brownfield redevelopment in order for a GIS to be created. The system is built up to accommodate data that is specifically created for a particular brownfields project. However this thesis has shown that existing state and local data can be used and do not have to be created specifically for brownfield redevelopment to facilitate better analysis of these sites. Although the GIS created by using existing data may not allow the detailed analysis that is provided by a built up GIS, it can still be used for very meaningful spatial analysis.

Many layers exist that can be incorporated into a GIS for brownfield purposes. Maps of aquifers and wetlands provided by the state can be used to determine if a brownfield site is located on them. These sites are important to identify as they normally have to be cleaned to the highest standards to prevent contamination of groundwater. Land use maps provided by the state or local communities can be used to determine the land use around brownfield sites. This can help a community propose redevelopment strategies that reflect surrounding uses. Local zoning maps can help identify what types of activity can occur on a brownfield site by-right. Parcel data provided by the assessor's office can be used to determine key land value and land use characteristics brownfield parcels and to identify other sites that meet similar characteristics and may be potential brownfield sites. The data can also be used to better document the land use around sites to help determine redevelopment strategies that reflect surrounding uses.

Since these data come from a variety of sources, they need to be combined in order to be utilized effectively. This thesis used a state land use layer for Boston, a list of sites provided by the Massachusetts Department of Environmental Protection, and assessor's data from the City of Boston to facilitate a land use analysis around the brownfield sites. They do not often contain detailed data and can be used for general analysis of a large area. Local data can be introduced to provide more detail in an analysis and to narrow the study area of analysis. These data are often more detailed and may require some effort to be included in a GIS. In addition some data sets such as the DEP sites list may be in tabular format and have to go through geo-referencing to be used for geographic analysis. In this case Microsoft Access was used to go through both state site databases to pull off only those records from within Boston so they could be mapped. Each of the two state lists was mapped using the geo-referencing procedures in MapInfo to create two point coverages of the sites.

There are several GIS packages that can be used to analyze brownfields information in a GIS. To develop the GIS for Boston and Codman Square, MapInfo was used to geo-reference the state list and create a point coverage for each of the state lists. ArcView was then used to edit these maps so they could be more easily used with the parcel coverage provided by Boston's assessor. ArcInfo was then used to buffer and intersect the site maps with the assessor's data. Finally a database package, Oracle SQL*Plus was used to analyze the assessor's data.

A community does not need all these programs in order to perform meaningful GIS analyses. Communities that need to develop maps as the point maps will need a GIS package like ArcView and MapInfo to perform the geo-referencing. In addition a relational database program that uses SQL, such as Microsoft Access is necessary if a community wants to be able to adequately prepare and utilize data that is in a one to many format such as the 21E data in Massachusetts. The databases set up for the sites in Massachusetts record each individual site number. This number can then be used to access several records in another table that relate to the site, such as the actions that have been performed on a site. If coverages need to be intersected or buffered to perform more complicated GIS functions a program like ArcInfo is necessary. In addition a community may find a database program such as Oracle useful. One of Oracle's main strengths is that it can be used in a multi-user setting that can allow many people simultaneous access to the database. However, in most cases a community will find a simple relational database such as Access can handle most of its needs.

From this discussion it appears that in most cases a community would need at least a GIS package like ArcView or MapInfo and a database package that can handle the many to one relationships in the state site data, like Microsoft Access, to build a basic GIS for brownfield redevelopment. The database program can be useful in pulling off the data in tabular databases that can be mapped. The GIS programs can perform geo-referencing procedures to associate geographic information to the tabular data so it can used as a map. The packages also allow for limited editing of maps, basic analyses, and maps to be overlaid and presented with each other. In many cases these programs can allow a community or agency, such as a CDC, with limited funds to access and perform basic data analysis. As these programs cost a lot less and require less training to use than more expensive and sophisticated GIS programs like ArcInfo, then can provide a lower cost way to develop a GIS for brownfields development.

If more advanced features are needed or desired in a GIS then the more expensive and sophisticated programs like ArcInfo and Oracle are needed. These programs cost a great deal and require a fair amount of training in order to be used, so their use should be carefully considered by communities or agencies with limited staff and resources. However, most of the analyses that are of interest to communities such as buffering are available in limited form in most of the more basic GIS programs.

These GIS packages can combine data together from various sources to facilitate meaningful spatial analysis. However the steps necessary to combine data from various state and local sources, as was done in the Boston and Codman Square GIS, can be tiresome and difficult at times. From the problems encountered in developing the brownfields GIS for Boston and Codman Square I will now outline several suggestions to improve how the data is obtained and its ability to be incorporated into a GIS

Facilitating Geo-Referencing

Although existing state and local data can be usefully combined in a GIS to perform analyses suited for brownfields redevelopment, efforts should be made to make these data more compatible in terms of format, projection, and structure. Although most of these problems are correctable they can slow down or prevent analysis of some data. The problems encountered in combining data on land use and contaminated properties in the GIS for the CSNDC are representative of the problems likely to encountered whenever data from different sources are combined.

Like most other states, the list of contaminated sites maintained by the Massachusetts Department of Environmental Protection was in tabular format and had to be geo-referenced in order for it to be mapped. The sites database also had to have the district field that was appended on the end of the street address for sites in Boston removed and placed in another field so the street address could be used in interactive geo-referencing. This was not a tremendously difficult task but was did consume time and was a distraction from the rest of geo-referencing. Once the lists were geo-referenced the street address information for several records were either missing, incomplete, or listed by site name. These addresses could not be automatically mapped, so they increased the amount of time spent in interactive geo-referencing. In addition several sites were mapped directly by hand on the map as the geo-referencing process did not map many sites.

To speed up and ease the geo-referencing process there are a few things that can be done to sites added to the release database in the future. Fortunately the database is set up so the area of the city where a site is located is recorded in a separate column and not with the street address. If a site is reported at a transportation facility or other institution, its street address should be recorded in the database and not its name. In addition the addresses that are entered should correspond with addresses in another source of data and this source should be noted in the documentation related to the lists of sites. When a new spill is reported the spelling of its street address should be double checked before it is entered into the computer to reduce the occurrence of misspellings. In addition by using one source of address information, and making sure each site can be mapped using this source, all addresses will be matched.

It might also be a good idea to record several different forms of location information in the sites databases so more sites can be matched. By using the TIGER files streets a record located on a street that did not exist in the files could not be mapped. In addition sites whose institution name were recorded, such as those at Logan Airport could not be geo-referenced automatically or interactively. If latitude and longitude, or map coordinates were also recorded in the database, these sites could be mapped using that information instead. So geo-referencing can be facilitated by double checking the street addresses of all sites before they are entered into the database, documenting which map was used to provide the street addresses, and by recording multiple types of location information with the data.

Even if the structure of the two DEP databases does not change, that structure should be better documented. While the files explaining the tables within each database were a good source of information about the databases, they did not adequately explain how the two databases of sites the release and sites databases, were related. In particular the explanation explaining why sites reported after October 1993 on the release database, could be on the sites database as well was not clear. There is a subtle and easily overlooked rationale that links the two that is not easily understood by reading this documentation. I only clarified the relationship between the two by talking directly with the DEP database manager. In the long term, the DEP release database should be improved to accommodate sites that may receive a tier ranking so there can be a clear difference between the two databases and no duplications between the two databases.

Improving Data Coordination

Beside geo-referencing, differences in map projections and formats could pose a problem in GIS analysis. In the case study since the geo-referencing of sites used the TIGER files, the resulting map did not line up with the assessor's parcel map. The site map was then edited to more closely line up with the parcel data. In addition, although a map was created by geo-referencing it had to be converted two times so it could be recognized by the GIS program we used in our final analysis. Although differences in projection of maps can result in maps not lining up, most GIS program provide tools to convert data between the different projection systems, and providing latitude and longitude information would be the most easily converted case.

In an ideal world, all GIS coverages of a certain type of data would be created from the same set of basemaps. As a result all maps would automatically match up. However, in the absence of such a system, the map used to create a coverage should be indicated in documentation about that layer to allow people to identify potential problems in advance. Currently programs such as the National Spatial Data Infrastructure (NSDI) are developing standards regarding how data are documented. Among the many methods being proposed to accomplish its goals is the standardization of metadata, or data about the data, that is provided with digital data. Those providing data can use the NSDI standards as a first effort in improving the information that accompanies the data to ease cross referencing with other digital data.

Efforts can also be taken by GIS vendors to improve the ability of data to be cross-referenced. Although most GIS packages do allow different types of map formats to be converted into the appropriate one for the package, they do not read the formats of other GIS packages directly. Future GIS programs could be designed so they can read and use the formats of other GIS programs directly. In the absence of such readability, data providers can provide data sets in a variety of formats so the coverages do not need to go through conversion procedures before they can be used.

Establishing a centralized data clearinghouse is another way cross referencing of data can be facilitated. The clearinghouse could provide data sets but also be used to help obtain, or point those using GIS for brownfield redevelopment, to data sets that can be used in their analyses. The MassDEP website can be seen as a more general clearinghouse for brownfields information. If a clearinghouse were set up it could provide information on which data sets are available for each type of brownfields analysis. A user could look at this information before a coverage was used to determine its projection system, map boundaries, source, basemap from which it was made, and other coverages with which it could be readily intersected. Making such data NSDI compliant could also help as that type of clearinghouse becomes standard. With this knowledge the steps needed to combine coverages together would be known in advance. However since there are state and local data sets that can be used for brownfields analysis, it might make sense to have a state clearinghouse and local clearinghouses set up that would work with each other to provide data relating to brownfields.

The clearinghouse could also provide technical support to those using GIS for brownfield redevelopment on geo-referencing, changing projection systems, preparing data, or any other GIS related topic. If needed the clearinghouse could perform intersections and other complicated GIS function for those unable to afford the advanced GIS packages needed for these analyses. As vendors begin providing Web-accessible GIS servers. However, it would make more sense if such a service handled much more than just brownfield analysis.

In the absence of any centralized data source, individual departments can make an effort to coordinate their data with information from other departments. The first step in this process would involve agencies opening up many of their databases to each other and the public. Steps can also be taken to structure the databases of each agency in a similar fashion, or have fields common across all departments. If agencies can not store similar data in the same fashion, tables that can correlate data from one source to another would be helpful.

An example of such a list would link addresses to parcel identification map to facilitate the geo-referencing of brownfield sites to individual parcels. In our analysis differences in how the address was recorded in the assessor's data and the state lists, made it difficult to map the addresses to each parcel. A cross-reference table that listed a parcel identification number for each address could have made it easier to map the addresses to parcels. It would also be helpful if each agency indicated the map from which a coverage was built, its projection system, and format somewhere when the data was obtained, so any potential problems could be identified in advance. This would better enable data to be shared among the various players in brownfield redevelopment to help improve knowledge of the sites and facilitate faster site clean up.

However, as the approach to dealing with brownfields becomes more inter-disciplinary, it is likely that each individual agency that comes into contact with brownfields may develop their own sets of maps. The proliferation of small brownfields GIS by each agency increases the need for attention to standards and cross-referencing tools. As both brownfield and GIS programs are most often developed at a state level, states can play an integral role in incorporating GIS technologies into brownfield redevelopment.

The state agencies concerned with brownfield development build on their existing role as a centralized data clearinghouse. The state agencies concerned with brownfields can help facilitate data coordination among agencies by requiring that brownfields information follow certain guidelines. The state lists of brownfield sites could be provided as a geo-referenced coverage to allow communities to avoid geo-referencing. The data on brownfield sites could also be structured in such a way as to speed geo-referencing by requiring each contaminated site to list multiple types of location information, such as street address, map coordinates, or latitude and longitude. The state can also provide better support on the data itself, through better documentation, metadata, telephone contact lists, or web pages.

In addition the state and or municipalities could set up map servers for brownfields related maps. A state map server could provide the public with an easy way to access state coverages of land use, aquifers, and wetlands in addition to census data for the state. These data could be used for preliminary analyses of a community's brownfield. The state server could then point a user to an appropriate local map server where local data sets such as assessor's data could be downloaded. These more detailed data could be used to refine the analysis using state data.

These efforts can enable a state to get brownfields information to the public more quickly and effectively. This information can then be used by the communities to better document and analyze their sites. The information obtained through such an approach can help these localities develop an overall strategy for their sites and develop local programs to help facilitate site redevelopment. Efforts that can be performed by localities could help ease the burden on the state to aid these redevelopment efforts. It could help increase the amount of people working on the brownfield issues so more energy can be spent trying to tackle the brownfields challenge to help return these sites to active use quickly.

The analysis in this thesis has shown that communities can use existing data and GIS tools to perform meaningful analysis. If a community can not obtain Pilot Project Funds, perhaps it could be provided funds to obtain what is in many cases costly GIS equipment, so it can perform analyses of its brownfields with existing data. This would link the equipment and software to the development of standards and cross-referencing efforts, rather than provide money to customized GIS for brownfields. Despite statewide brownfield programs, the sites are really a local problem. By having the state provide these communities with the equipment they need so they can analyze the data themselves, some of the pressure on the state to perform these analyses can be relieved. While it may cost the state a great deal to provide GIS programs to communities, in the long run it may help the state accomplish its goals of brownfield redevelopment, by getting the information flowing about these properties.

A combination of tables, buffered maps, and orthographic images has been shown to add much more than any one can alone to data analysis, due to inconsistencies between the maps. Therefore flexible detailed local analysis with general purpose GIS tools and map layers can be valuable, and facilitated by many of these steps. While an analysis of brownfields that uses GIS can not take the place of a planning process for each site, it can at least better inform planners and others dealing with brownfield parcels to guide the development of reuse strategies. GIS analysis can be a tool to better inform site redevelopment options but not the mechanism to propose a specific reuse strategy on each site.

In some cases due to legal restrictions on what can happen on brownfield sites, commercial uses may not be proposed for an individual parcel that is surrounded by all residential uses within a 100 feet. Therefore commercial reuse strategies should be pursued only for sites that are located within commercial corridors, and not in residential areas. For such sites in residential areas it might make more sense to redevelop them for residential use or as improved open space. A broader reuse strategy might also consider rezoning vacant residential lands to facilitate their redevelopment as the concentration of such parcels is higher near the sites.

In the past contaminated properties have been a hindrance to development in many areas. The threat of legal liability for clean up costs for these properties often limited discussion of redeveloping the parcels. Partly because of this there has been limited information available about the sites. As brownfield programs continue to develop programs to help limit liability and facilitate site redevelopment it is important for those involved with brownfields to obtain as much knowledge as they can about the properties. Although GIS can not be used to answer all of the questions relating to brownfield redevelopment, it can at least be used to improve the overall quality and amount of information available about the sites. As such it can be used as part of a more comprehensive brownfields program to help formulate overall brownfield strategies for the sites in most communities.

Brownfields are a problem. They are often ugly, costly to redevelop, and located in areas facing other societal problems. However the problem has been compounded by a lack of information flow. GIS can aid in getting the information flowing that is related to these sites, that in many cases is lacking or blocked. As it is the state government that most often develops brownfield redevelopment programs, it can play a vital role in getting GIS into communities, increasing knowledge of brownfield sites, and getting the properties successfully returned to active use.

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APPENDIX A: DATA DICTIONARY OF THE SITES DATABASE

The sites database is used to keep track of spills of hazardous material reported to the Masschusetts Department of Environmental Protection before October 1, 1993 when the latest revisions to the Massachusetts Contingency Plan took effect. In addition to these sites, the database also keeps tracks of sites reported after October 1, 1993 that have received a tier classification within a year of the first report. This database can then be considered a list of tiered sites in the state. In addition to the two tables below, a third table called descript.dbf also exists that has detailed information on the chemicals released, their source, and location on each site.

Sites.dbf

SITE_ID	Release tracking number (RTN)
ERB_NO	If a site was referred from the Emergency Response Branch prior to 1993, its spill number
EPA_NO	Records the EPA site number if a sites is assigned one
SITE_NAME	The site name used by DEP staff
ADDRESS	Most correct street address for a site
TOWN_NAME	Town where the site is located
COUNTY	County where the site is located
REGION	DEP region in which located
ZIP	Site Zip Code
TRSTAT	Tier status
CUR_STATUS	Current level of remedial activity
PET_HAZARD	Type of site contamination (petroleum, hazardous, or both)
NPL_21E	Level of federal involvement on a site
INITIATED_BY	Branch, division, or agency that reported the site
ACTION_BY	Source of funds for remedial action
PUBLIC_INV	Whether or not the site has been designated a Public Involvement Site
REM_CODES	Type of response measure taken at a site
LIST_LTBI	Date site was first listed in publication as LTBI
LIST_CONF	Date site was first listed in publication as Confirmed
LIST_DEL	Date site was first listed in publication as Deleted
LIST_REM	Date site was first listed in publication as Remedial
SITE_STAT	Current site status based on most recent submittal
REQ_TYPE	Types of requirements for LTBI sites
REQ_DUE	Date deadline by which the required action must be completed

Sactions.dbf

SITE_ID	RTN
REGION	DEP Region in which located
TS_SDATE	Date response action submittal was made
RAS_TYPE	The type of response action that was performed
RA_STATUS	The status of the response action
RAO_CLASS	The way the response action outcome (RAO) is categorized
AUL_NOTICE	Date when an activity and use limitation (AUL), if any, took effect
RESTR_TYPE	AUL Restriction type

APPENDIX B: DATA DICTIONARY OF THE RELEASE DATABASE

The release database is used to keep track of spills of hazardous material reported to the Masschusetts Department of Environmental Protection after October 1, 1993 when the latest revisions to the Massachusetts Contingency Plan took effect. If a site where a spill has been reported after October 1, 1993 receives a tier ranking it is no longer tracked in the release database but in the sites database although it will appear in both databases. The sites in the release database that do not also appear in the sites database can be considered a list of untiered sites in the state.

Release.dbf - primary release information

SITE_ID	RTN
TOWN	Town name
OFF_TOWN	Official town name
SITE_ADD	Release address
SITE_ZIP	Release Zip Code
LOC_AID	Location aid (release name)
NOTE_DATE	Notification date
CATEGORY	Category

Actions.dbf - actions that occurred against releases

SITE_ID	RTN
ACT_DATE	Action Date
ACT_TYPE	Action Type

Chemical.dbf - chemicals that were released

SITE_ID	RTN
CHEM_NAME	Chemical Name
AMT_REL	Amount Released
AMT_QNT	Quantity Released

Location.dbf - location type for a release

SITE_ID	RTN
LOC_TYPE	Location Type

Source.dbf - sources of the release

SITE_ID	RTN
SRC_TYPE	Source Type

APPENDIX C: SAMPLE ORACLE SQL*PLUS QUERIES

To perform many of the data analyses in this thesis the program Oracle SQL*Plus was used. SQL*Plus is a series of commands that can be issued in the program to access and analyze data. A query is a series of SQL*Plus commands that tells Oracle what to do with the tables in the database. Below are a few sample queries that were performed for this thesis.

The query below is using the data from the parcels that lie within 100 meters of the tiered sites in Codman Square. This table was given the name pre100pr. The first query computes the number of parcels in the coverage, total lotsize area, and total area within the buffer. These numbers are then used in the next query

```
SQL> select count(parcel_id), sum(lotsize), sum(area)
  2  from pre100pr
  3  where area > 0 and landuse IS NOT NULL;
-- Press return to continue or Control-C to stop --
COUNT(PARCEL_ID) SUM(LOTSIZE)  SUM(AREA)
---------------- ------------ ----------
             867     10342285 434617.903
```

This next query uses the results above to help determine the percentage of parcels, lotize, and area each land use type makes up in the coverage. The pre100pr table is linked in the query to a table called landuse96. This table is a lookup table that relates each land use to a land use type of commercial/industrial, exempt, or residential.

```
SQL> select landuse, count(parcel_id), ((count(parcel_id)/867)*100) perpar,
sum(lotsize), ((sum(lotsize)/10342285)*100) perlot, sum(area),
((sum(area)/434617.903)*100) perarea
  2  from pre100pr
  3  where area > 0 and landuse IS NOT NULL
  4  group by landuse;
```

The query below computes average values by land use. It also uses the landuse96 table since it has a column that corrects mistyped land uses from the parcels coverage. The land use codes listed on the left refer to parcels classified as: apartments, commercial, condominiums, commercial land, exempt property, exempt 121-A property, industrial, one family housing, two family housing, three family housing, small apartment house (4-6 units), residential multi-use properties, and residential land.

```
SQL> select newlu, avg(lotsize), avg(landval), avg(buildval), avg(totalval),
avg(landval/lotsize)
  2  from landuse96 l, parcel96 p
  3  where l.landuse=p.landuse and lotsize > 0
  4  group by newlu;
-- Press return to continue or Control-C to stop --
NE AVG(LOTSIZE) AVG(LANDVAL) AVG(BUILDVAL) AVG(TOTALVAL) AVG(LANDVAL/LOTSIZE)
-- ------------ ------------ ------------- ------------- --------------------
A    13722.0496   220170.228     607043.84    827214.067           44.9500062
C     18058.515   556739.338    1423678.39    1980002.98           673.860848
```

```
CD   8424.37032   186.389724   56016.1651   56202.5548              .173077986
CL   11060.6641   87029.5547   11930.2976   98959.8522              13.6421484
E    104595.933    726843.12   1130962.92   1857806.04              20.6636827
EA    23293.322   527099.352   2521378.74   3048478.09              26.1316497
I    41675.9341   303816.703   495551.824   799368.526              12.7333172
R1    5158.9749   65143.4452   78342.5486   143485.994              20.9177764
R2   4878.88516   62753.2329   89265.8456   152019.078              18.7175982
R3   3634.57137   56365.4178   89504.5847   145870.003              21.9802713
R4   3645.34293   70225.1603   177078.541   247303.702              33.3161929
RC   5044.16597   136279.949   407831.223   544111.172              38.6621176
RL   6071.40449   11269.6788   377.606687   11647.2855              2.59685688

13 rows selected.
```

The next query is the same as above, except the landuse96 table is used to group data by one of three landuse types.

```
SQL> select lutype, avg(lotsize), avg(landval), avg(buildval), avg(totalval),
avg(landval/lotsize)
  2  from landuse96 l, parcel96 p
  3  where l.landuse=p.landuse and lotsize > 0
  4  group by lutype;
-- Press return to continue or Control-C to stop --

LUTYPE     AVG(LOTSIZE) AVG(LANDVAL) AVG(BUILDVAL) AVG(TOTALVAL)
AVG(LANDVAL/LOTSIZE)
---------- ------------ ------------ ------------- ------------- -------------
-------
Com/Ind        20034.15    358787.69    798187.786    1156852.22
340.211193
Exempt       98333.7211   711597.263    1237089.29    1948686.55
21.0810366
Residen      5232.94643   59167.8415    97221.9927    156389.834
18.8891353
```